DOES PROCESS QUALITY OF INPATIENT CARE MATTER IN POTENTIALLY PREVENTABLE READMISSION RATES?

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ABSTRACT

Objective: To examine the association between process quality of inpatient care and risk-adjusted, thirty-day potentially preventable hospital readmission (PPR) rates.

Data Sources/Study Setting: This was an observational cross-sectional study of nonfederal acute-care hospitals located in two states California and Florida, discharging Medicare patients with a principal discharge diagnosis of heart failure, acute myocardial infarction, or pneumonia January through December 31, 2007. Data were obtained from the Healthcare Cost and Utilization Project State Inpatient Database of the Agency for Healthcare Research and Quality, Centers for Medicare and Medicaid Services Hospital Compare database, and the American Hospital Association Annual Survey of Hospitals.

Study Design: The dependent variable of this study is condition-specific, risk-adjusted, thirty-day potentially preventable hospital readmission (PPR). 3M's PPR software was utilized to determine whether a readmission was potentially preventable. The independent variable of this study is hospital performance for process quality of inpatient care, measured by hospital adherence to recommended processes of care. We used multivariate hierarchical logistic models, clustered by hospitals, to examine the relationship between condition-specific, risk-adjusted, thirty-day PPR rates and process quality of inpatient care, after taking clinical and socio-demographic characteristics of patients and structural and operational characteristics of hospitals into account.

Principal Findings: Better performance on the process quality metrics was associated with better patient outcome (i.e., low thirty-day PPR rates) in pneumonia, but not generally in two cardiovascular conditions (i.e., heart failure and acute myocardial

infarction). We found no evidence of an interaction between process quality metrics and condition-specific hospital volume with respect to 30-day PPR.

Conclusion: Adherence to the process quality metrics currently in use by CMS is associated with risk-adjusted, thirty-day PPR rates for patients with pneumonia, but not with cardiovascular conditions. More evidence-based process quality metrics closely linked to 30-day PPR rates, particularly for cardiovascular conditions, need to be developed.

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CHAPTER I: INTRODUCTION

Background

A readmission is a return hospitalization to an acute care hospital that follows a prior admission from an acute care hospital. Readmissions following discharge from acute care hospitals are frequent, costly, and sometimes life-threatening events. Older people have substantially higher rates of hospital readmission than the general population. About 20 percent of Medicare fee-for-service beneficiaries who were discharged after hospitalization were readmitted within 30 days after discharge from hospitals, and 34 percent were readmitted within 90 days [1]. Medicare expenditure for potentially preventable readmissions is as much as $12-17 billion a year [1, 2].

Readmission reflects gaps in care transition. The transition from inpatient to outpatient setting is a critical and vulnerable point along the care continuum. Many patients are discharged "quicker and sicker" than before, and they often are left unprepared at discharge. Particularly, older patients with chronic and multiple comorbid conditions experience difficulties during the transition between inpatient and community setting because as burden of self-care responsibility is placed, if discharged to home, on patients or their family caregivers. Family caregivers often lack necessary skills and knowledge to provide sustained care to the elderly patients with chronic and multiple comorbid conditions [3].

The time period covered by a "readmission" can vary. It can be a repeated admission within 7, 30, 90 days, or 1 year of discharge from the initial admission. The lack of uniformity in defining readmission may yield inconsistent reports of the readmission rates in adult population. The readmission timeframe directly affects the risk. Hospitals have greater control over the clinical processes during the hospitalization and the discharge process. The shorter readmission timeframe (7 to 30 days) more closely reflects quality of care during the index hospitalization, while a longer timeframe (90+ days) reflects the effectiveness of community-based, chronic monitoring and maintenance systems [4]. The number of unpreventable readmissions tends to increase with an increasing readmission timeframe [5].

Readmission rates vary substantially by hospitals and geographic areas. One analysis suggests that the rate for the highest quartile of all-cause hospital readmission rates was 25%, compared to 13% in the lowest quartile [1]. Other studies reported variation in 30-day, all-cause readmission rates among hospitals for three common medical conditions, heart failure, acute myocardial infarction, and pneumonia [6, 7]. The relative differences in 30-day, all-cause readmission rates across the 10^{th} to 90^{th} percentiles of hospital performance was 23.7% for heart failure (21.9% vs. 27.1%), 15% for acute myocardial infarction (18.4% vs. 21.2%), 24.4% for pneumonia (16.4% vs. 20.4%) [6, 7].

Readmission rates vary by geographic areas. The 30-day readmission rate after discharge among Medicare beneficiaries was 45% higher in the five states with the highest rates (Maryland-22%, New Jersey 21.9%, Louisiana-21.9%, Illinois-21.7%, and

21.3%-West Virginia) than in the five states with the lowest rates (Idaho-13.3%, Utah-14.2%, Oregon-15.7%, Colorado-16.2%, and New Mexico-16.3%) [1]. Medicare beneficiaries who were admitted in Boston for five conditions (myocardial infarction, stroke, hip fracture, gastrointestinal bleeding, or potentially curative surgery for cancer) had a 64% higher readmission rate than those admitted in New Haven for these conditions [8].

The substantial variation in readmission rates among hospitals and geographic areas suggests ample room for improvement. Geographical variation in readmission rates may be partially explained by local capacity of health care systems or local physician practice patterns [6, 8, 9]. While we do not yet fully understand organizational characteristics explaining variation in readmission rates among hospitals, variation even after risk-adjustment among hospitals suggests that some hospital factors are at play. A small but growing body of research indicates that hospital teaching status, ownership, cardiac capability, nurse staffing, hospital size, and hospital volume are associated with readmission rates [10-13].

Policymakers are anxious to reduce preventable readmissions because they may represent an opportunity to ensure quality of care and patient safety while lowering health care costs. While not all readmissions are avoidable and unnecessary, many unplanned readmissions shortly after discharge are thought to be preventable; prior randomized controlled trials have shown that enhancing inpatient process care, such as comprehensive discharge planning and care coordination, reduce readmissions [14-17]. Since July 2009, the Centers for Medicare & Medicaid Services (CMS) has posted

30-day all-cause readmission rates for heart failure, acute myocardial infarction, or pneumonia by hospitals for Medicare patients on its Hospital Compare web site. Beginning October 1, 2012, inpatient payments to hospitals will be reduced if a hospital experiences excessive readmissions within a specified period following discharge for a heart attack, heart failure, or pneumonia.

Hospital performance for potentially preventable hospital readmission rates is gaining momentum as a reportable quality indicator for pay-for-performance for hospitals. Several states, including New York, Florida, Texas, Maryland, Massachusetts, Colorado, and Hawaii, use potentially preventable readmission rates for public reporting. However, little attention has paid to the association between the potentially preventable hospital readmission rates and quality of inpatient care. If potentially preventable readmission rates are to serve as a suitable marker of hospital performance, we need to make sure that hospital performance for quality of inpatient care is inversely related to preventable hospital readmission rates. While previous studies that examined the association between quality of inpatient care and mortality rates as a clinical outcome found a modest inverse association [18-22], no prior work to date has investigated the link between potentially preventable readmission rates and hospital performance for quality of inpatient care.

Purpose of Study

This study contributes to the understanding of factors associated with the potentially preventable readmission rates. The specific aim is to investigate, at the hospital level, whether hospital performance for process quality of inpatient care delivered during initial hospitalization is related to potentially preventable readmission rates. The research questions examined are the following.

Research Question 1

Our main focus is on the association between hospital level performance for process quality and potentially preventable readmission rates. Is better process quality of inpatient care associated with lower potentially preventable readmission rates across hospitals? Stated differently, are patients discharged from hospitals with better quality of inpatient care less likely to be readmitted for potentially preventable reasons? Because Question 1 has not been directly investigated in prior literature, we construct our hypothesis based on similar literature on other patient outcomes. Specifically, we generate a hypothesis based on two lines of prior research that examined association between 1) readmission (but not preventable) and process quality ***at patient level*** and 2) mortality and process quality ***at hospital level***. Studies of the association between readmission and process quality at patient level have generally found an inverse association between readmission and process quality [23-27]. Studies that investigated the link between mortality and performance for process quality metrics at hospital level found an inverse association [18-22]. We extrapolate from these findings to hypothesize that hospitals' performance for process quality of inpatient care is inversely

associated with potentially preventable rates of rehospitalization. Because we lack data on process quality metrics at patient level, we rely on data aggregated at hospital level. Previous research that investigated an association between mortality and process quality metrics also used data on aggregated at the hospital level. The hypothesized association is estimated after patients' individual characteristics and other hospital factors are accounted for.

Research Question 2

Hospital volume has been shown to be associated with better quality for many conditions [12, 28]. We are interested in investigating whether experience in caring for patients, measured by condition-specific hospital volume, moderates the hypothesized association between process quality of inpatient care and potentially preventable readmission rates. We are looking for an interaction effect. Among the hospitals, does the influence of process quality of inpatient care on potentially preventable readmission rates vary with hospital condition-specific volume? Although high volume hospitals may have better process quality, we suspect that hospitals' performance for process quality metrics may exert its influence differently in large volume and small volume hospitals. We hypothesize that the magnitude of the postulated association between potentially preventable readmission rates and process quality of inpatient care is greater for low-volume hospitals than large-volume hospitals. High-volume hospitals may provide care not captured in quality metrics, which might have benefit beyond the observed quality metrics in avoiding preventable readmissions. For example, high-volume hospitals may have implemented care coordination programs or they may

provide care through specialized centers, such as a heart valve center. Also, high-volume hospitals are more likely to be familiar with clinical practice guidelines of professional societies and are more likely to adhere to them to maintain a positive reputation. Consequently, the magnitude of the association of the adherence to quality metrics with preventable readmission rates may be greater in low-volume hospitals than high-volume hospitals.

CHAPTER II: LITERATURE REVIEW

Overview

This dissertation examines the association between process quality of inpatient care and potentially preventable readmission rates. This chapter will review the relevant literature concerning the factors associated with preventable hospital readmission. Related topics to be discussed include 1) patient-level factors predictive to preventable readmissions, 2) link between patient-level process quality of inpatient care and preventable readmissions, 3) link between hospital-level process quality of inpatient care and preventable readmissions, and 4) hospital-level factors associated with preventable readmissions. Next, the conceptual model for the present study is presented.

Patient-level factors associated with preventable readmissions

Prior research on early or unplanned readmissions has devoted much attention to the patient-specific risk factors including clinical, demographic, and social factors. In general, it has been suggested that clinical factors have more influence on the risk of readmission than do demographic and social factors. *Clinical factors* for early or unplanned readmission which have been identified and documented in prior studies include presence of comorbidities [1, 5, 29-46], severity of illness [5, 47-51], chronic conditions (relative to acute conditions) [52, 53], index hospitalization for medical conditions (relative to surgical procedure) [1, 5, 54], functional disability [1, 55, 56], mal-nutrition [57, 58], medication dosage change shortly before discharge [59], the prior hospital utilization (typically 12 month) [1, 29, 30, 37, 38, 41, 48, 51, 59-63], and

prolonged length of stay during index hospitalization [1, 10, 29, 35, 37, 38, 41, 48, 51, 55, 62, 63].

Demographic factors matter in early or unplanned readmissions. Demographic factors predictive of early or unplanned readmissions include increasing age [1, 5, 30, 34-36, 38, 44, 45, 48, 51, 62, 64], male sex [1, 10, 29, 36, 44, 46, 48, 50, 61], Black race [1, 13, 36, 43, 49, 65], Hispanic race [66], and rural residence [10, 38, 52, 54]. While much attention has been paid to the patient risk factors, many of the clinical and demographic risk factors that have been identified are not considered modifiable.

Finally, several *social factors* are associated with an increased likelihood of early or unplanned readmissions. Social risk factors which have been identified in prior studies include low socio-economic status [55, 67-69], Medicaid payer status [10, 34, 41, 49, 65], Medicare payer status [41, 48, 65, 70], discharge to post-acute care facilities (relative to home) [35, 37, 49, 65], discharge against medical advice [48, 49], living alone [55, 71], lacking self-management skills [55], and lack of documented patient or family education [30].

Link between patient-level process quality of inpatient care and preventable readmissions

Previous literature has documented that quality of inpatient care exerts an influence on the risk for early or unplanned readmission at patient level [23-27]. Ashton et al. (1995) performed a case-control study of 2513 male veteran patients in 12 Veterans

Affairs hospitals who had heart failure (n=748), diabetes (n=593), or obstructive lung disease (n=1172) to investigate the association between quality of inpatient care and unplanned readmission within 14 days [23]. The authors assessed quality of care, using following criteria: the admission workup, evaluation and treatment during the stay, and criteria for readiness for discharge. After adjustment for demographic and clinical factors, the study found that 1 of 5 readmissions in patients with heart failure, 1 of 7 readmissions in patients with diabetes, and 1 of 12 in patients with obstructive lung disease were attributable to substandard care. They concluded that suboptimal quality of inpatient care increases the risk for unplanned early readmission in patients with heart failure, diabetes, or obstructive lung disease. Because the definition of the readmission in the study was restricted to Veterans Affairs hospitals, the attributable risks might be underestimated if some patients were readmitted to non-Veterans Affairs hospitals. The finding may not be generalizable to 1) patients who use non-VA hospitals, 2) patients with other conditions, and 3) female patients.

Ashton et al's (1997) meta-analysis of 29 studies published from 1973 to through 1993 examined the association between 31-day readmission and quality of inpatient care that are under the control of care providers [24]. The authors classified the datasets according to quality of care received as being either normative (defined as care conforming to accepted standards of routine hospital practice), substandard (defined as care failing to meet standards), and exceptional (defined as exceeding standards). Patients who received relatively low quality ('substandard' or 'normative') were 55 percent more likely to be readmitted within 31 days after discharge than those who received care of higher quality ('normative' or 'exceptional') (CI: 1.25-1.92). Patients

who received ‘substandard’ care were 24 percent more likely to be readmitted within 31 days after discharge than those who received ‘normative’ care, yet the confidence interval included 1.0 (CI: 0.99-1.57). Studies counting only ‘unplanned readmissions’ had positive results while ‘all readmissions’ tended to have inconclusive results. Similarly, studies defining readmission as return hospitalization to “any hospitals” were found to have conclusive results, compared to those defining them as readmission to “same hospital”. The review concluded that early readmission is associated with lower process quality of inpatient care.

Weissman et al. (1999) investigated the association of “related adverse readmission” with quality of care [25]. They sampled 1758 Medicare patients hospitalized for congestive heart failure and pneumonia performed in four states, and conducted a case-control study. To determine quality of care, the study used two measures: explicit measure, i.e., predetermined criteria, and implicit measure, i.e., post hoc subjective assessments by physician. After adjusting readmission risk scores, there were small but statistically significant differences in quality of inpatient care during index hospitalization (measured by both explicit and implicit criteria) between patients who subsequently experienced “related adverse readmissions” and those who did not experience “related adverse readmissions”. Interestingly, the magnitude of the relation between related adverse readmission and quality was greater in pneumonia than in congestive heart failure. An intriguing finding is that while generally smaller and statistically insignificant, patients experiencing “other admissions” (i.e., readmissions not deemed to be related or adverse) tended to have lower quality of care during their index hospitalization compared with non-readmitted patients.

A review article by Benbassat and Taragin (2000) found that up to 48% of all readmissions were related to sub-optimal care during the index hospitalization, such as poor resolution of the main problem and unstable therapy at discharge [26]. Up to 75% of all readmission were believed to be preventable if standard care were used after index discharge. The review concluded that while global readmission rates are not a useful indicator of quality of care, high readmission rates of patients with defined conditions such as heart failure or diabetes may identify quality of care problems.

Link between hospital-level process quality of inpatient care and preventable readmissions

Prior studies have examined the association between process quality of inpatient care and clinical outcome measures, yet much attention has been paid to the mortality [18-22, 72, 73]. While most studies suggest that better performance for process measures is associated with lower mortality for heart failure [21, 22], acute myocardial infarction [18-22], and pneumonia [21, 22], some studies reported mixed findings for heart failure [72] or disassociation [73].

Several prior studies examined the association between hospital-level processes quality of inpatient care and cardio-vascular readmission [74, 75] and combined mortality or all-cause readmission [72]. Table 1 summarized these studies. All of these studies used data from the Organized Program to Initiate Lifesaving Treatment in Hospitalized

Patients with Heart Failure (OPTIMIZE-HF) registry and, thus the context of care was heart failure.

Hernandes et al. (2010) investigated whether hospital performance for process quality metrics were associated with patient-level post discharge outcomes including 1-year or 60-day cardiovascular readmission, i.e., subsequent admission for a cardiovascular reason, and 1-year or 60-day mortality [74]. The study employed following emerging process quality measures that were not among the heart failure performance measures used by CMS: any beta-blocker for patients with left ventricular systolic dysfunction (LVSD); evidence-based beta-blocker for patients with LVSD; warfarin for patients with atrial fibrillation; aldosterone antagonist for patients with LVSD; implantable cardioverter-defibrillator for patients with ejection fraction ≤ 35%; and referral to disease management. Hospitals' performance for process measures were calculated by dividing the number of patients for whom the process of care was documented by the number of patients who were eligible. The study found significant associations between hospitals' performance for process quality measures and 1-year cardiovascular mortality, with the exception of the warfarin and referral to disease management. However, none of the hospital-level process quality of inpatient care measures were significantly associated with lower risk of 60-day or 1-year cardiovascular readmission, with the exception of the beta-blocker, after controlling for patient demographic and clinical factors and hospitals' heart failure volume. OPTIMIZE-HF hospitals (n=141) were self-selected and hence, the external validity of this finding may be limited if participating hospitals differed from nonparticipating hospitals.

Patterson et al. (2010) investigated the association between hospital-level performance for process quality metrics and 1-year cardiovascular readmission and 1-year mortality [75]. They used process quality measures endorsed by CMS: 1) discharge instructions that address diet, exercise, medications, and relevant follow-up care for patients discharged to home; 2) assessment of left ventricular function; 3) prescription of an angiotensin converting enzyme (ACE) inhibitor or angiotensin receptor blocker (ARB) at discharge to eligible patients with left ventricular systolic dysfunction without contraindications; and 4) smoking cessation counseling for patients who had smoked within 1 year of admission. Additionally, they included another measure that was not endorsed by CMS: beta-blocker for patients with LVSD. The study found that hospital-level performance for process measures including discharge instructions, prescription of an ACE inhibitor or ARB, and smoking cessation counseling was not associated with lower patient-level cardiovascular readmission at 1 year, after accounting for patient clinical and demographic factors and hospital-level volume. However, none of the process metrics were associated with 1-year mortality. They observed a statistically significant positive association between hospitals' adherence to assessment of left ventricular function and cardiovascular readmission at 1 year. The external validity of this finding remains uncertain because participating hospitals (n=150) may differ from nonparticipating hospitals.

Fonarow et al. (2007) examined the relationship between performance measures for patients hospitalized with heart failure and relevant clinical outcomes including 60- to 90-day mortality and combined mortality or all-cause readmissions [72]. They included five heart failure inpatient performance measures: 1) discharge instructions, 2) evaluation

of left ventricular systolic function, 3) ACE inhibitor or ARB for left ventricular systolic dysfunction, 4) smoking cessation advice and counseling, and 5) anticoagulant at discharge for patients with atrial fibrillation. Of the 5 heart failure performance measures, 2 were significantly associated with reduced risk of combined mortality or all-cause readmissions: ACE inhibitor/ARB for LVSD and beta-blocker at discharge. Interestingly, ACE inhibitor/ARB for LVSD was a marginally significant predictor for mortality (Hazard Ratio: 0.61; 95% CI, 0.35-1.06), but it turned out to be significant for the combined mortality or readmission (OR: 0.51; 95% CI, 0.34-0.78). While this study did not explicitly investigate the association of ACE inhibitor/ARB for LVSD and readmission, this finding suggests that ACE inhibitor/ARB for LVSD may be an independent predictor for all-cause readmissions. Similar to the other works from the OPTIMIZE-HF registry, this work did not account for other hospital characteristics. Again, the external validity of this finding remains uncertain because participating hospitals (n=91) were self-selected.

Organizational-level factors associated with preventable readmissions

While no previous studies examined organization factors associated with preventable readmissions, several studies examined the hospital characteristics associated with 30-day, all-cause readmission rates [11-13, 54]. Table 2 summarizes these studies. Using a 1974-1977 Medicare data set, Anderson et al. (1985) examined hospital factors associated 60-day all-cause readmission rates. While teaching hospitals and small size hospitals tended to have higher readmission rates, this finding needs to be interpreted

with caution because the analytic modeling was not specified [54]. Using national claims data for Medicare patients with heart failure discharged from US hospitals in 2006 to 2007, Joynt et al. (2011-a) examined hospital characteristics associated with 30-day, all-cause readmission rates [11]. Ownership, cardiac capability, nurse staffing, and hospital size are independently associated with the likelihood of 30-day, all-cause readmission. Specifically, likelihood of 30-day, all-cause readmission was higher for patients discharged from hospital without cardiac services and hospitals with partial cardiac services (compared with full cardiac services), and with low nurse staffing (compared with high nurse staffing). Likelihood of readmission was also higher for patients discharged from both for-profit and public hospitals (compared with not-for profit) and small size hospitals (compared with large hospitals). Likelihood of readmission was higher for patients discharged from hospitals located in counties with low median income (compared with high income), but the association did not persist after accounting for other hospital characteristics.

Using same claims data and cohort, Joynt et al. (2011-b) examined the association between condition-specific hospital volume and patient outcomes including 30-day, mortality rates and 30-day, all-cause readmission rates [12]. Hospital volume of patient with heart failure was captured with a categorical variable (low: 25-200 discharge over 23-month study period, medium: 201-400, high: >400). While they found that among patients with heart failure, being admitted to a hospital with a higher volume of patients with heart failure was associated with lower 30-day, mortality rates, a similar significant association was not observed in 30-day, all-cause readmission rates. The strongest effect of volume on mortality was observed in the group of hospitals with the lowest

volume. The findings may not have internal validity because the study employed a standard logistic regression while not accounting for clustering of patients within hospitals. The finding is inconsistent with other studies which found inverse associations between hospital volume and 30-day readmission for infection after coronary artery bypass surgery [35, 76]. While examining prior literature on mortality is beyond the scope of this review, it is worth reviewing another work that examined the relation of hospital volume and mortality for medical conditions.

Ross et al. (2010) used national claims data for Medicare patients with heart failure discharged from US hospitals in 2004 to 2006 to examine the association between hospital volume and the 30-day mortality rate for patients who are hospitalized for heart failure, acute myocardial infarction, or pneumonia [28]. Hospital volume was inversely associated with 30-day mortality rates for all conditions. Consistent with the findings from Joynt et al. (2011-b), the association between volume and outcome was attenuated as the hospital's volume increased. While this study did not examine readmission rates as outcome variable, it suggests that condition-specific hospital volume may matter in readmission rates.

Using national claims data for Medicare patients with heart failure, acute myocardial infarction, or pneumonia discharged from US hospitals in 2006 to 2008, Joynt et al. (2011-c) investigated whether being discharged from minority-serving hospitals was associated with the likelihood of all-cause, 30-day readmission [13]. To identify minority-serving hospitals, the authors calculated the proportion of its Medicare patients who are black and categorized hospitals in the highest decile of proportion of black

patients as minority serving. They found that among patients with heart failure, being discharged from minority-serving hospitals was associated with 14% higher odds of readmission than patients from non-minority-serving hospitals. Among patients with acute myocardial infarction, being discharged from minority-serving institutions was associated with 22% higher odds of readmission. Among patients with pneumonia, being discharged from minority-serving institutions was associated with 18% higher odds of readmission. These findings were not accounted for other hospital characteristics. After accounting for other hospital characteristics, black patients with acute myocardial infarction from minority-serving hospitals had 22% higher odds of readmission than non-black patients from non-minority serving hospitals; black patients from non-minority serving hospitals had 11% higher odds of readmission than non-black patients from non-minority serving hospitals. Black patients with heart failure from minority-serving hospitals had 10% higher odds of readmission than non-black patients from non-minority serving institution; black patients from non-minority serving hospitals had 2% higher odds of readmission than non-black patients from non-minority serving hospitals. Black patients with pneumonia from minority-serving hospitals had 22% higher odds of readmission than non-black patients from non-minority serving institution; black patients from non-minority serving hospitals had 12% higher odds of readmission than non-black patients from non-minority serving hospitals. While authors noted that their analytic models (multivariate logistic regression) included within hospital clustering, they did not provide further details on their statistical modeling.

Gaps in the previous literature

Although the majority of the prior research on readmission focuses on individuals' clinical and socio-demographic risk factors, a small but increasing body of research has investigated whether hospitals' structural and operational characteristics may influence the likelihood of all-cause readmission. There have been many attempts to investigate the association between hospitals' performance for process quality of inpatient care and clinical outcomes, but much focus lied on mortality. Although findings have been mixed, the majority of the studies on mortality suggest that higher performance for process quality of inpatient care is associated with lower mortality.

To date, no prior literature has examined the link, at hospital level, between potentially preventable readmission rates and hospital performance for process quality of inpatient care. Several studies, at patient-level, indicated the inverse association between (early, unplanned, or early unplanned) readmission and antecedent quality of inpatient care. A few recent studies, using data from OPTIMIZE-HF registry, have investigated the link, at hospital-level, between hospital performance for process quality of inpatient care for heart failure and readmission after index hospitalization for heart failure. While these studies generally suggest a disassociation of hospital-level process quality of inpatient care for heart failure with cardiovascular or all-cause readmissions, it is uncertain whether the finding can be generalizable to other medical conditions such as pneumonia or acute myocardial infarction and to non-OPTIMIZE-HF institutions. These studies employed longer readmission timeframes, i.e., 60-day to 1-year, which are not suitable for evaluating process quality of inpatient care during the index

hospitalization. Furthermore, hospital characteristics that have been suggested to influence the clinical outcomes were not accounted for in any of these OPTIMIZE-HF studies and thus, results may be biased.

This dissertation will overcome shortcomings and fill the gap in the prior literature by investigating the association between hospital performance for process quality of inpatient care and risk-adjusted, 30-day potentially preventable readmissions (PPR) after hospitalization for three common medical conditions- acute myocardial infarction, heart failure, and pneumonia-, controlling for organizational characteristics. Based on the prior literature, we constructed the conceptual model for the present study and it is presented below.

Conceptual Model

The conceptual model guiding this work is displayed in Figure 1. Because we investigate hospital effects on patient outcomes, we formulate a hierarchical model wherein patients are nested in hospitals. The constructs illustrated in Figure 1 are measured at two levels. Patient characteristics and the outcome, PPR, are measured on patients and hospital level factors, including process quality, are measured on hospitals. We highlight two key constructs in this study with bold lines around the boxes: process quality and the outcome-whether patients are readmitted for potentially preventable reason(s) or not. Our research questions are captured in Arrow A (Research Question 1) and B2 (Research Question 2). The analysis for Question 1 relies on controlling for confounders, whereas the analysis for Question 2 examines an interaction. The rest of the arrows -A, B1, C, D, E, F, G, and H- represent variables that are controlled in the study.

The within hospital regression coefficients express the associations of patient-level explanatory variables on the patient outcome (PPR) within a given hospital; the between hospital regression coefficients express the associations of the hospital-level explanatory variables on the group mean of the patient outcome (PPR rate). Note that process quality is measured on hospitals, not on patients.

We capture process quality with hospitals' adherence to recommended clinical process of care. Specifically, the construct of process quality is operationalized in an aggregate measure: the proportion of patients who received the recommended care out of all the patients who were eligible for the recommended care.

We examine the link between hospitals' performance for process quality and the group mean of PPR, i.e., PPR rate, which is captured by Arrow A (Research Question 1). We hypothesize that hospitals with better performance for process quality of inpatient care would have lower PPR rates. This hypothesized association is controlled for patients' risk factors and hospital characteristics. We then explore whether experience in caring for patients, measured by condition-specific hospital volume, moderates the relationship between process quality of inpatient care and PPR rates, which is captured by Arrow B2 (Research Question 2).

We capture patient clinical characteristics with following measures: severity (measured by prior hospitalization), comorbidity (measured by Elixhasuer comorbid conditions), and cardiac procedures for AMI patients (measured by coronary artery bypass graft or percutaneous transluminal coronary angioplasty). The association between clinical characteristics and outcome is captured in Arrow D, E, and F. We capture patient socio-demographic characteristics with following measures: age, sex, race, income (measured by median household income state quartile for patient ZIP Code), which is captured by Arrow G. We also control patients' discharge location, which is captured in Arrow H. The structural and demographic characteristics of the hospitals (Arrow A and C) are included for purposes of statistical control. We capture hospital structure with following measures: hospital ownership status, teaching intensity, Magnet status (a proxy of nurse care environments), condition-specific hospital volume (a proxy of experience with managing condition), capacity to perform cardiac catherization (a proxy of high-tech cardiac services), Medicare disproportionate-share hospital (DSH) index (a proxy of the proportion of poor patients), and system affiliation. While we do

not generate formal hypotheses, we consider hospitals with more experiences, high-tech, and better nurse care environment would be associated with the better patient outcome, i.e., low PPR rates. We capture hospital demographic composition with the following measures: condition-specific average number of Elixhauser comorbid condition, and condition-specific proportion of patients having a history of hospitalization. We capture hospital location with Metropolitan Statistical Area.

CHAPTER III: METHODS

Subjects and Databases

Three diagnosis-based patient cohorts were defined as follows: patients aged 65 years or older enrolled in Medicare fee-for-service program for 2007 who had been discharged from the acute care hospital in California and Florida with the principal diagnosis of heart failure (International Classification of Disease, Ninth Revision, Clinical Modification [ICD-9-CM] codes 402.01, 402.11, 402.91, 404.01, 404.03, 404.11. 404.13, 404.91, 404.93, or 428.0-428.9, acute myocardial infarction (ICD-9-CM codes 410.0-410.9), and pneumonia (ICD-9-CM codes 480.8, 480.9, 481, or 482.0-487.0). The conditions were selected in that they are common, costly causes of hospitalization. Since this study used state-level discharge records, rather than national-level records, out-of-state patients' readmissions could not be ascertained. Therefore, out-of-state patients were excluded. Patients who died are excluded because they are not eligible for readmissions. An admission with a discharge status of "left against medical advice" was also excluded because hospitals did not have the opportunity to deliver intended care.

Data on inpatient hospital discharges records for the 24-month period from January 1, 2006, through December 31, 2007 were drawn from complete hospital discharges in the Healthcare Cost and Utilization Project State Inpatient Database (herein referred to as the HCUP-SID) of the Agency for Healthcare Research and Quality (herein referred to as the AHRQ) and the Supplemental Files for Revisit Analyses (herein referred to as the Revisit Files). The HCUP-SID is the largest collection of all-payer, uniform, state-based, inpatient administrative data. The HCUP database contains

discharge-level rather than patient-level data, and there is no unique patient identifier that can serve to track readmissions. To facilitate analyses that focus on multiple hospital stays by the same patient, AHRQ created the Revisit Files which can be linked to the HCUP state-level databases to identify multiple patient visits in the hospital setting while adhering to strict privacy regulations. Two data periods were used in the analysis. From HCUP-SID database for the 12-month period from January 1, 2007, through December 31, 2007, we tracked potentially preventable readmissions, severity, comorbidities, and post-discharge characteristics. Next, the HCUP-SID file for the 12-month period from January 1, 2006, through December 31, 2006 was used to track history of hospitalization within 1 year before the index admission.

Data on quality of inpatient care were obtained from the Centers for Medicare and Medicaid Services (CMS) Hospital Compare database for 2007. The measures of quality of inpatient care cover the corresponding clinical conditions that were tracked for readmissions: heart failure, acute myocardial infarction, and pneumonia, between January 1 and December 31, 2007.

We used two data sources for hospital characteristics: American Hospital Association Annual Survey of Hospitals files and the HCUP-SID file. Data on hospital structural characteristics (such as size and ownership status) where patients were treated during initial hospitalizations were obtained from the American Hospital Association Annual Survey of Hospitals files for 2007. The American Hospital Association Annual Survey of Hospitals collects data each year from hospitals nationwide regardless of their membership status and typically obtains an overall response rate of 85% or greater (AHA,

1999). Data on hospital operational and demographic characteristics (such as mean number of patient comorbid conditions and condition-specific hospital volume) were directly derived from inpatient discharge records from HCUP-SID file.

To create the analytical file, inpatient discharge records from the HCUP-SID file were linked to the AHA-ASH files for information on hospitals where patients were treated during index hospitalization. The HCUP-SID file provides information on the hospital identifier used by AHA. Then, this dataset was merged with CMS Hospital Compare database using Medicare provider number.

Variables & Measures

Dependent Variable: Potentially Preventable Readmissions (PPR)

Our outcome variable is a dichotomous measure of whether a patient was readmitted for potentially preventable reasons (coded 0) or not (coded 1). We employed the potentially preventable readmission (herein referred to as the PPR) methodology developed by 3M Health Information Systems. 3M PPR algorithm defines PPRs as return hospitalizations within a specified time interval that may have resulted from deficiencies in the process of care in the initial admission, inadequate discharge planning, or lack of post discharge follow-up [5]. Based on all combinations of diagnoses for an index admission and for a readmission, 3M algorithm determines whether a particular diagnosis of readmission was clinically related to the index admission and, therefore, was potentially preventable. The PPR software uses primary and secondary diagnostic codes,

procedure codes, and all-patient refined diagnosis related group (APR-DRG) codes to determine the preventability of readmissions. In developing PPR logic, clinical panels applied criteria for clinical relevance and preventability.

It should be noted the limitation of the 3M PPR measure. PPR measure requires validation studies assessing reproducibility and reliability of the judgment process. While 3M PPR methodology needs validation studies, it is being used in several state agencies including New York, Florida, Texas, Maryland, Massachusetts, Colorado, and Hawaii. It was also used by the Medicare Payment Advisory Commission (MedPAC), an independent Congressional agency.

The 3M PPR logic can be divided into three phases. In phase I, each admission is assigned an APR-DRG to identify globally-excluded admissions and Non-events. Globally-excluded admissions include admissions for major or metastatic malignancies, multiple trauma, and burns. A Non-event is an admission to a non-acute care facility such as a nursing home or an admission to an acute care hospital for non-acute care (e.g., rehabilitation or convalescence). Non-events during the readmission time window between an initial admission and a readmission are ignored in the determination of PPR. The following admissions are classified as Non-events: 1) admission to non-acute care facilities, 2) admissions to an acute care hospital for patients assigned to the base APR-DRG for rehabilitation, aftercare, and convalescence, and 3) same-day transfers to an acute care hospital for non-acute care.

In phase II, the readmission time interval is applied to the remaining admissions resulting in each admission being preliminarily classified into one of four admission

categories: Initial Admission, Readmission, Only Admission, and Transfer Admission. The Initial Admission is an admission that is followed by a clinically-related readmission (i.e., PPR). The Initial Admission initiates a readmission chain which is a sequence of PPRs that are all clinically-related to the Initial Admission. An Only Admission is an admission for which there is neither a preceding Initial Admission nor a PPR within the readmission time window. Transfer Admissions are a subset of Only Admissions that have a discharge status of "transferred to an acute care hospital". Transfer Admissions are not eligible to be PPRs. Note that Initial Admissions and Only Admissions represent admissions that are at risk for being followed by a PPR.

In phase III, PPRs are identified based on the clinical relationship between the Initial Admission and readmissions, within the readmission time window. A readmission is considered clinically-related to the Initial Admission if the reason for the readmission falls into one of following categories:

- Medical readmission for a continuation or recurrence of the reason for the Initial Admission, or for a condition closely related to the reason for the Initial Admission
- Ambulatory care sensitive conditions as designated by the AHRQ
- All other readmissions for a chronic problem that may be related to care either during or after the initial admission
- Medical readmission for an acute medical condition or complication that may be related to or may have resulted from care during the initial admission or in the post-discharge period after the Initial Admission

- Readmission for a surgical procedure to address a continuation or a recurrence of the problem causing the Initial Admission
- Readmission for a surgical procedure to address a complication that may be related to or may have resulted from care during the initial admission

Our outcome variable is a dichotomous measure of whether a patient readmitted for potentially preventable reasons (Initial Admission: coded 0) or not (Only Admission: coded 1). The PPR software allows researchers to specify additional criteria to be PPRs, including readmission setting (i.e., readmission to the same-hospital or to the across hospitals) and readmission time interval. We used across-hospital readmissions rather than same-hospital readmissions. Using same-hospital readmission may generate a serious bias in favor of institutions whose patients are readmitted elsewhere [77]. We employed 30-days as readmission time interval because the shorter readmission window is useful for evaluating quality of care during index hospitalization.

Explanatory variable: Clinical Process Quality

The explanatory variable for the present study is hospital-level process quality of inpatient care. Process measures are procedures, treatments, or interventions that are designed to improve patient outcomes. Unlike outcome measure, such as mortality and readmission rates, process measures reflect actionable for quality improvement activities as they are under the control of hospitals and health care providers [78]. In addition, process measures may provide positive spillover effects, such as raising health care

providers' awareness about clinical guidelines and enhancing overall commitment to a high quality of care [79]. Hospitals that better adhere to the recommended clinical process care may devote their resources to improving quality of care and hence, are likely to perform well in other process and outcome measures. Hence, hospitals' performance on process quality metrics may be an indicator for a latent construct of unobserved aspects of quality of inpatient care.

We used CMS Hospital Compare hospital process of quality measure set. The Hospital Quality Alliance (HQA), a national public-private collaboration between the CMS and hospital organizations, report hospitals' performance on process of care measures through the Hospital Compare. These measures evaluate a hospital's adherence to recommended clinical process of care for heart attack, heart failure and pneumonia. Six of the measures assess process quality of care for heart attack, three of the measures assess process quality of care for heart failure, and six of measures assess clinical process quality of care for pneumonia. Beneficial effects of these measures on the readmission are well documented [80-83].

Measures for heart attack include: (1) aspirin at arrival; (2) aspirin at discharge; (3) beta-blocker at arrival; (4) angiotensin converting enzyme (ACE) inhibitor for left ventricular systolic (LVS) dysfunction; (5) fibrinolytic medication within 30 Minutes of arrival; and (6) PCI within 90 minutes of arrival. Measures for heart failure include: (1) written discharge instructions or education material that address activity level, diet, discharge medication, follow-up appointment, weight monitoring, and what to do if symptoms worsen; (2) evaluation of left ventricular function; and (3) prescription of an angiotensin converting enzyme (ACE) inhibitor or angiotensin receptor blocker (ARB) at

discharge to eligible patients with left ventricular systolic dysfunction without contraindications. Measures for pneumonia include: (1) pneumococcal vaccination, (2) initial antibiohjotic timing; (3) influenza vaccination; (4) blood culture performed in the emergency department prior to initial antibiotic received in hospital; (5) appropriate initial antibiotic selection; and (6) oxygenation assessment. For each measure, a hospital's performance was calculated as the proportion of all eligible patients who received the indicated care. To ensure the stability of the measures, hospitals with fewer than 15 patients for an individual measure were excluded.

Composite measures enable us to improve the ability to detect differences by capturing the spectrum of care of a condition into a single measure [84, 85]. Hence, we also constructed two condition-specific composite measures from the individual measures. First, composite measures at admission and at discharge within conditions were calculated using a weighted average of performance across all measures, respectively. AMI measures assessed at admission included: 1) aspirin at arrival, 2) beta-blocker at arrival, and 3) percutaneous coronary interventions (PCI) within 90m of arrival. AMI measures assessed at discharge included: 1) angiotensin converting enzyme inhibitor (ACE Inhibitor) or Angiotensin Receptor Blockers (ARB) for Left Ventricular Systolic Dysfunction (LVSD), 2) aspirin at discharge, and 3) beta-blocker at discharge. Pneumonia measures assessed at admission included: 1) assessed and given influenza vaccination and 2) assessed and given pneumococcal vaccination. Pneumonia measures assessed at discharge included: 1) initial antibiotic(s) within 6h after arrival, 2) oxygenation assessment, 3) the most appropriate initial antibiotic(s), and 4) initial emergency room (ER) blood culture performed prior to first hospital dose of antibiotics.

There was no HF composite measure assessed at admission. HF measures assessed at discharge included: 1) ACE inhibitor or ARB for LVSD, 2) evaluation of LVS Function, and 3) discharge instructions.

Second, a global composite measure was calculated by aggregating all individual measures within conditions using a weighted average of performance across all measures. A global measure was not calculated for heart failure because there was no admission composite measure. Therefore, for pneumonia and AMI, three composite measures (i.e., admission composite measure, discharge composite measure, and global composite measure) were constructed, respectively, and for heart failure, only one composite measure (i.e., discharge composite measure) was calculated. Hospitals with fewer than 15 patients for an individual measure were not included in the calculation of the composite score. However, as long as a hospital reported a denominator of at least 15 cases for at least one measure, the hospital had composite scores.

There is no flawless measure; the CMS Hospital Compare measures also have several potential limitations. The data are based on voluntarily self-reported measures, and consequently it is likely that there is a systematic scoring bias in hospitals' incomplete reporting across all measures. That is, hospitals might not report specific performance scores if they poorly performed in the particular measure. Another issue related to Medicare's Hospital Compare is reliability of the submitted data. While CMS audits submitted data, it is not adequate for validation of the data because CMS audit process is based on random sample of hospitals.

Patient-level control variables

We adjusted patients' clinical, socio-demographical, and post discharge characteristics that may influence the likelihood of patient being readmitted for potentially preventable reasons. We captured patients' socio-demographic background by several measures: age (continuous variable measured in years), sex (dichotomous variable: female=1, male=0), race/ethnicity (categorical variable: White=0, Black=1, Hispanic=2, others=3), and median household income state quartile for patient ZIP Code (categorical variable: poorest=1, poor=2, wealthy=3, wealthiest=4). We captured patients' severity by history of hospitalization within 1 year (categorical variable: no history of hospitalization=0, hospitalized for same condition with the index admission and no history of hospitalization for other condition=1, no history of hospitalization for the same condition with the index admission and hospitalized for other diagnosis=2, hospitalized for both the same and other condition with the index admission=3). We identified patients' comorbid conditions with Elixhauser index by a series of dummy variables of whether patients had a comorbid condition (coded 1) or not (coded 0). The Elixhauser index captures the presence of 31 diseases using administrative data. We captured disposition of the patient at discharge (categorical variable: routine/home=0, nursing home=1, home health care=2, other=3). For patients with acute myocardial infarction, we captured the location of acute myocardial infarction by two dummy variables of whether patients had an "anterior AMI" (coded 1) or not (coded 0) and whether patients had an "other AMI" (coded 1) or not. In addition, we also captured cardiac procedures by dummy variables of whether patients with acute myocardial infarction underwent coronary artery bypass graft (coded 1) or not and of whether

patients underwent percutaneous transluminal coronary angioplasty (PTCA) (coded 1) or not (coded 0).

Hospital-level control variables

We controlled for a number of hospital level factors, including structural, operational, and demographic characteristics of hospitals. Structural and operational characteristics included hospital ownership status (categorical variable: public, non-profit, for-profit), teaching intensity (categorical variable: non-teaching if zero resident-to-bed ratio, low-intensity if 0-0.05 resident-to-bed ratio, medium-intensity if 0.05-0.6 resident-to-bed ratio, and high-intensity if >0.6 resident-to-bed ratio), Medicare disproportionate-share hospital (DSH) index as a proxy of the proportion of poor patients, whether a hospital had a better nurse care environments (coded 1) or not (coded 0), measured by Magnet status, whether a hospital was affiliated with health care systems (coded 1) or not (coded 0), and hospital location based on Metropolitan Statistical Area (categorical variable: metro, micro/division, or rural). A dummy variable was also constructed to indicate the State. We captured condition-specific hospital volume of the elderly patients (continuous variables).

We captured hospital demographic composition with several measures: hospital average number of Elixhauser comorbid condition for each condition, proportion of patients having a history of hospitalization for both the same and other condition with the index admission for each condition.

Analytic approach

Because of the hierarchical structure of the data, with patients nested within hospitals, we used hierarchical generalized linear modeling, a multilevel logistic regression model, to measure the relationship between process quality inpatient care and PPR.

We first fit a null model with no fixed effects and random intercept effects for hospitals to test whether significant variation in PPR exists across hospitals.

$$\log\left(\left(p_{ij}/1-p_{ij}\right)\right) = \beta_{0j} \quad \text{..... (eq.1)}$$

$$\beta_{0j} = \gamma_{00} + u_{0j} \quad \text{..... (eq.2)}$$

$$\log\left(\left(p_{ij}/1-p_{ij}\right)\right) = \gamma_{00} + u_{0j} \quad \text{..... (eq.3)}$$

where $p_{ij}$is the probability of the *i*th patient in the *j*th hospital PPR, u_{0j} is the random effect at the hospital level, and $\gamma_{00}$is the regression intercept. We find the single equation model eq.3 by substituting eq.2 into eq.1. Then we modeled patient level predictors of probability of PPR.

$$\log\left(\left(p_{ij}/1-p_{ij}\right)\right) = \beta_{0j} + \gamma_{p0}\boldsymbol{X}_{pij} \quad \text{..... (eq.4)}$$

$$\beta_{0j} = \gamma_{00} + u_{0j} \quad \text{..... (eq.5)}$$

$$\log\left(\left(p_{ij}/1-p_{ij}\right)\right) = \gamma_{00} + \gamma_{p0}\boldsymbol{X}_{pij} + u_{0j} \quad \text{..... (eq.6)}$$

where X_{pij} are p explanatory variable at the patient level. Again, the intercept was allowed to vary across hospitals (i.e. to be random). All independent variables at patient level were estimated as fixed effects. In other words, the between-hospital variances of their associations to the outcome are fixed to zero. Our final model included patient level predictors and hospital level predictors.

$$\log\left(\left(p_{ij}/1-p_{ij}\right)\right) = \beta_{0j} + \gamma_{\mathrm{p}0}\boldsymbol{X}_{pij} \quad \text{..... (eq.7)}$$

$$\beta_{0j} = \gamma_{00} + \gamma_{0q}\boldsymbol{Z}_{qj} + u_{0j} \quad \text{..... (eq.8)}$$

$$\log\left(\left(p_{ij}/1-p_{ij}\right)\right) = \gamma_{00} + \gamma_{\mathrm{p}0}\boldsymbol{X}_{pij} + \gamma_{0q}\boldsymbol{Z}_{qj} + u_{0j} \quad \text{..... (eq.9)}$$

where X_{pij} are p explanatory variable at the patient level and Z_{qj} are q explanatory variable at the hospital level. While the intercept was allowed to be random, all independent variables at both patient and hospital level were estimated as fixed effects. This model allows us to examine whether the hospital-level explanatory variables, such as process quality of inpatient care, are associated with the hospital-level estimate of the proportion of patients who were readmitted for potentially preventable reasons (i.e., the PPR rate in each hospital).

In the fixed-effects part, we calculated odds ratios (OR) and their 95% confidence intervals (95% CI). In the random-effects part, we obtained the variance and their 95% confidence intervals (95% CI) at the hospital level. In order to quantify the importance of variance at hospital level, we calculated intraclass correlation coefficient (ICC) and the

median odd ratio (MOR). Intraclass correlation coefficient (on the logit scale) indicates the proportion of variance that is accounted for by the hospital level. ICC is calculated by using following formula: $\rho_I = \sigma_{u^2}/(\sigma_{u^2} + \sigma_{e^2})$, where σ_{e^2} is the variance of the standard logistic distribution, estimated by $\pi^2/3 = 3.29$. In addition to the ICC, the MOR was calculated and examined to the degree of heterogeneity. The MOR converts the variances into the OR scale which is comparable with the OR of the patient- or hospital-level explanatory variables and thereby enables us to interpret variance more intuitively. The MOR can be interpreted as how much a patient's odds of being readmitted would increase if the patient moved to a hospital with larger random intercept (i.e. higher PPR rates). The MOR is calculated by using the following formula: $\text{MOR} = \exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

Our outcome variable is a binary measure of whether a patient readmitted for potentially preventable reasons (Initial Admission, coded 0) or not (Only Admission, coded 1). While most patients in the cohorts of acute myocardial infarction and pneumonia had 1 candidate discharge record of either Initial Admission or Only Admission within a 1-year period, multiple candidate discharges were frequent in the patient cohort of heart failure. We randomly selected 1 discharge if the multiple candidate discharges records were observed within a 1-year period. As mentioned earlier, we excluded patients who died during index hospitalization because they are not eligible for readmissions. We lack of data on post-discharge patient mortality. We were not able to track process measure-specific 30-day PPR that match specific quality

measures because we lack patient-level data on the eligible population and those who received the indicated care.

The associations between process quality measures and condition-specific PPR were modeled separately. This work performed all statistical analyses using STATA 11.2 (StataCorp, College Station, TX). A *P* value of less than .05 was considered statistically significant.

CHAPTER IV: RESULTS

Overall, 42051 heart failure, 21635 acute myocardial infarction, and 36384 pneumonia discharges were analyzed. Mean age of the heart failure cohort was 80.5, 54.5% were female, and 72.2% were white. Mean age of the acute myocardial infarction cohort was 78.9, 49.3% were female, and 79.4% were white. For the pneumonia cohort, mean age was 80.3, 55.5% were female, and 76.7% were white.

Hospital Characteristics

The characteristics of the hospitals are summarized in Table 3. Overall, 427 hospitals were included in the analysis of heart failure, 380 in acute myocardial infarction, and 426 in pneumonia. The numbers of hospitals were different by conditions as the number of hospitals which reported performance for process quality measures were different by conditions. As noted, for descriptive purposes, this study divided hospitals into three groups according to their condition-specific, crude 30-day PPR rates. The mean crude 30-day PPR rates are 16.63% for heart failure, 17.11% for acute myocardial infarction, and 11.50% for pneumonia, respectively. Among hospitals with low crude 30-day PPR rates for heart failure, a larger proportion of hospitals were private non-profit, had cardiac catherization capabilities, were located in urban areas, and had a low DSH index. Among hospitals with low crude 30-day PPR rates for pneumonia, a larger proportion of hospitals had cardiac catherization capabilities, had Magnet status, were located in urban, were located in California, had a low DSH index, and cared for less

severe patients (measured by proportion of patients with history of prior hospitalization for both pneumonia and other conditions). Among hospitals with low crude 30-day PPR rates for acute myocardial infarction, a larger proportion of hospitals were private non-profit, had cardiac catherization capabilities, had Magnet status, were located in urban, were located in California, had a low DSH index, and cared for less severe patients (measured by proportion of patients with prior hospitalization for both acute myocardial infarction and other conditions).

Hospitals with high condition-specific patient volume, with cardiac catherization capabilities, and with urban location had low crude 30-day PPR rates across all three conditions.

Hospital performance on process quality measures

Hospital performance for individual process quality measures and the composite measures are summarized in Table 4. In general, there was little variation in the measures of process quality of inpatient care for all conditions across hospitals. In the case of five out of six individual measures for acute myocardial infarction, hospitals performing in the top 25th percentile adhered to the recommended care more than 99% of the time. For the measures of heart failure, hospitals performing in the top 25th percentile adhered to the recommended care more than 95% of the time for all three individual measures. For the measures of pneumonia, hospitals performing in the top 25th percentile adhered to the recommended care more than 94% of the time for all six

individual measures. There were relatively more variations among lower-performing hospitals compared to the higher-performing counterparts. In general, there were relatively more variations in the following measures: evaluation of LVS function for heart failure patients, PCI within 90m of arrival for acute myocardial infarction patients, and assessed and given influenza vaccination and pneumococcal vaccination for pneumonia patients.

Hierarchical Analyses

Within Hospitals (Level 1) Results

While our primary focus lies on hospital characteristics associated with PPR rates, we briefly report key findings on the association between patient-level risk factors and 30-day PPR. Patient level factors that are associated with 30-day risk-adjusted PPR are summarized in Table 4 for heart failure, Table 6 for acute myocardial infarction, and Table 7 for pneumonia. Multivariate results indicate that patients who were discharged to home health care or nursing home are more likely to be readmitted for a potentially preventable reason compared to those who were discharged to home (i.e., routine discharge) across all three conditions. Specifically, for heart failure patients, discharge to home health care had increased the odds of being readmitted for a potentially preventable reason by 17-18% ($p<.001$) and discharge to nursing home increased the odds of being readmitted for a potentially preventable reason by 57-58% ($p<0.001$) compared to those discharged to home or self-care, after controlling for patient- and

hospital-level characteristics (Table 3). For acute myocardial infarction and pneumonia patients, the magnitudes of the increased odds of 30-day PPR were stronger than heart failure; discharge to home health care increased the odds of being readmitted for a potentially preventable reason by 30-41% ($p<0.001$) compared to discharge to home or self-care, after controlling for patient- and hospital-level characteristics, and discharge to nursing home care increased the odds of being readmitted for a potentially preventable reason by 87-99% ($p<0.001$) compared to discharge to home or self-care (Table 4). In the case of pneumonia patients, the magnitude of the increased odds of 30-day PPR was stronger than other conditions. Discharged to home health care increased the odds of being readmitted for a potentially preventable reason by 34-36% compared to those discharged to home or self-care ($p<0.001$) and discharge to nursing home increased the odds of being readmitted for a potentially preventable reason by 110-114%, after controlling for patient- and hospital-level characteristics ($p<0.001$) (Table 7).

Patients with more severity, measured by history of prior admission, also had higher odds of 30-day PPR across all three conditions. For the heart failure cohort, history of prior hospitalization in 12 months for both heart failure and other conditions increased the odds of being readmitted for a potentially preventable reason by 83% compared to no history of hospitalization in 12 months ($p<0.001$) (Table 5). For the pneumonia cohort, magnitude of the increased odds of 30-day PPR was slightly stronger than heart failure cohort; history of prior hospitalization in 12 months for both pneumonia and other conditions increased the odds of being readmitted for a potentially preventable reason by 85-86% compared to patients without history of hospitalization in 12 months ($p<0.001$) (Table 6). For acute myocardial infarction patients, magnitude of the

increased odds of 30-day PPR was weaker than other two conditions; prior hospitalization in 12 months for both acute myocardial infarction and other conditions increased the odds of being readmitted for a potentially preventable reason by 47-50% as compared to patients without history of hospitalization in 12 months ($p<0.001$) (Table 7). History of prior hospitalization in 12 months with the same diagnosis as the initial admission was also a strong risk factor for 30-day PPR across all conditions although magnitude of increased odds of 30-day PPR is weaker than history of prior admissions for both same diagnosis and other conditions for the initial admission. For acute myocardial infarction, undergoing coronary artery bypass grafting (CABG) decreased the odds of being readmitted for a potentially preventable reason by 22-23% compared to patients without the procedure ($p<0.01$). For acute myocardial infarction, undergoing percutaneous transluminal coronary angioplasty (PTCA) increased the odds of being readmitted for a potentially preventable reason by 12-14% ($p<0.05$).

Patients with renal failure and chronic pulmonary disease had increased odds of 30-day PPR across all three conditions. Specifically, for heart failure patients, having renal failure increased the odds of being readmitted for a potentially preventable reason by 24% ($p<0.001$) and having chronic pulmonary disease increased the odds of being readmitted for a potentially preventable reason by 11% ($p<0.001$) (Table 5). For acute myocardial infarction patients, having renal failure increased the odds of being readmitted for a potentially preventable reason by 18-21% ($p<0.001$) and having chronic pulmonary disease increased the odds of being readmitted for a potentially preventable reason by 17-19% ($p<0.001$) (Table 6). For pneumonia patients, having renal failure increased the odds of being readmitted for a potentially preventable reason by 13-14%

($p<0.01$) and having chronic pulmonary disease increased the odds of being readmitted for a potentially preventable reason by 19% ($p<0.001$) (Table 7). In addition to these two comorbid conditions, heart failure patients with iron deficiency anemias, diabetes with chronic complications, fluid & electrolyte disorders, peripheral vascular disorders, or psychoses had increased odds of 30-day PPR ($p<0.05$ for all). While acute myocardial infarction patients with diabetes (both with and without complications) and with peptic ulcer disease had increased odds of 30-day PPR; those with metastatic cancer had decreased odds of 30-day PPR ($p<0.05$). Lastly, pneumonia patients with rheumatoid arthritis, congestive heart failure, or weight loss had higher odds of 30-day PPR ($p<0.05$ for all).

Several socio-demographic factors were associated with 30-day PPR. For heart failure patients, advanced age and Hispanic race (compared to white), were significantly associated with increase odds of 30-day PPR ($p<0.05$ for all). For pneumonia patients, female sex and other races (compared to white) were associated with decreased odds of 30-days PPR ($p<0.05$ for all). For acute myocardial infarction patients, none of the socio-demographic factors were found to be associated with odds of 30-day PPR.

Between Hospitals (Level 2) Results

The results of our 22 separate unconditional models consistently indicate that statistically significant variance in PPR rates exists at the hospital level, underlining the need to look at the hierarchical nature of PPR ($p<0.001$ for 20 models and $p<0.01$ for 2

out of 22 models). Degree of variance in PPR rates between hospitals varies by medical conditions; variance is smaller in cardiovascular conditions than in pneumonia. Variance between hospitals in unconditional models (Model 1) for heart failure ranged from 0.029 to 0.030, for acute myocardial infarction ranged from 0.023 to 0.040, and for pneumonia ranged from 0.105 to 0.113. The reason for slightly different variances between hospitals in the same condition is due to different number of observation in each model. Variance between hospitals in the full models without interaction (Model 3) for heart failure ranged from 0.015 to 0.016, for acute myocardial infarction ranged from 0.005 to 0.023, and for pneumonia ranged from 0.058 to 0.062.

As mentioned earlier, due to limitations of the ICC for non-linear outcomes, we also calculated the median odds ratio (MOR). After controlling for patient-and hospital-level characteristics (Model 3), for a randomly selected heart failure patient changing hospital, from low to high odds of being readmitted within 30 days for a potentially preventable reason, the odds would in median increase by 1.13-fold (Median Odds Ratio=1.13 for all of the four heart failure measures). After controlling for patient-and hospital-level characteristics, for a randomly selected acute myocardial infarction patient changing hospital, from low to high odds of being readmitted within 30 days for a potentially preventable reason, the odds would in median increase by from 1.07-fold to 1.16-fold (range of Median Odds Ratio for 9 AMI measures: 1.07-1.16). For an pneumonia patient changing hospital, from low to high odds of being readmitted within 30 days for a potentially preventable reason, the odds would increase by from 1.26-fold to 1.27-fold (range of Median Odds Ratio for 9 PN measures: 1.26-1.27). In other words, a randomly selected pneumonia patient's median odds ratio of being

readmitted within 30 days for a potentially preventable reason(s) would increase 1.26- to 1.27-fold if he/she was discharged from a hospital with a higher PPR rates.

Association between process quality of inpatient care and condition-specific, 30-day risk-adjusted PPR rates

-Main effect

Summary of association of condition-specific PPR with individual and composite process quality measures after controlling patient- and hospital-level factors are summarized in Table 8 for heart failure, Table 9 for acute myocardial infarction, and Table 10 for pneumonia, respectively. Full results are presented in Appendix Tables (Appendix Tables 1 to 4 for heart failure, 5 to 13 for acute myocardial infarction, and 14 to 22 for pneumonia).

We found that the existence of inverse association between process quality of inpatient care and 30-day, risk-adjusted PPR rates varies by medical conditions; that is, we observed the hypothesized inverse association between process quality of inpatient care and 30-day, risk-adjusted PPR rates in pneumonia but not generally in two cardiovascular conditions (i.e., heart failure and acute myocardial infarction). For pneumonia, as performance for process quality of inpatient care increases, 30-day, risk-adjusted hospital PPR rates tend to decline after adjusting for patient clinical and demographical characteristics and hospital characteristics (Table 10). There was a significant inverse association between all 3 composite measures (i.e., admission,

discharge, and global composite) and 30-day, risk-adjusted PPR rates ($p<0.05$ for each measure). Specifically, for every one point increase in the admission composite score out of 100 possible points, the odds of being readmitted for a potentially preventable reason decreased by 2% ($p<0.01$). For the discharge composite measure, a weaker magnitude of association was observed than admission composite measure; for every one point increase in the discharge composite score out of 100 possible points, the odds of being readmitted within 30 days for a potentially preventable reason decreased by 0.2% decrease in the odds of being readmitted within 30 days for a potentially preventable reason ($p<0.05$). For every one point increase in the global composite score out of 100 possible points, the odds of being readmitted within 30 days for a potentially preventable reason decreased by 0.8% ($p<0.01$).

For the individual pneumonia process quality measure, two out of six individual measures had a statistically significant inverse association with 30-day, risk-adjusted PPR rates ($p<0.05$ for each measure) and other three measures exhibited marginally significant inverse trends ($p<0.10$ for each measure). Specifically, for every one point increase in the "assessed and given influenza vaccination" out of 100 possible points, the odds of being readmitted within 30 days for a potentially preventable reason decreased by 0.3% decrease in the odds of being readmitted within 30 days for a potentially preventable reason ($p<0.05$). "the most appropriate initial antibiotic(s)" turned out to be inversely associated with 30-day, risk-adjusted PPR rates; that is, for every one point increase in the most appropriate initial antibiotic(s) out of 100 possible points, the odds of being readmitted within 30 days for a potentially preventable reason decreased by 3.4%, ($p<0.01$).

The rest of the individual measures for pneumonia exhibited marginal influence on the PPR rates, with the exception of "Initial ER Blood Culture Performed Prior To First Hospital Dose of Antibiotic". Specifically, for every one-point increase in "Assessed and Given Pneumococcal Vaccination" the odds of being readmitted within 30 days for a potentially preventable reason decreased by 0.2% (p=0.08). For every one-point increase in "Initial Antibiotic(s) within 6h After Arrival" the odds of being readmitted within 30 days for a potentially preventable reason decreased by 0.7% (p=0.05). Lastly every one point increase in "Oxygenation Assessment" the odds of being readmitted within 30 days for a potentially preventable reason decreased by 3.3% (p=0.05).

Contrary to the pneumonia, the quality scores for the two cardiovascular conditions were generally found to be unrelated to 30-day, risk-adjusted PPR rates after adjusting for patient clinical and demographical characteristics and hospital characteristics. For acute myocardial infarction, neither composite nor individual measures had a statistically significant relation to 30-day, risk-adjusted PPR rate, with the exception of "PCI within 90m of arrival" (Table 9). There was a relatively larger variation in hospital performance for this measure, "PCI within 90m of arrival", compared to other process quality measures for acute myocardial infarction. For every one point increase in "PCI within 90m of arrival, the odds of being readmitted within 30 days for a potentially preventable reason decreased by 0.4% (p<0.01). The admission composite measure was marginally significant, but had a modest influence on the 30-day, risk-adjusted PPR rates; for every one point increase in admission composite measure, the odds of being readmitted within 30 days for a potentially preventable reason

decreased by 1% (p=0.09). For other individual and composite measures for acute myocardial infarction, although statistically insignificant, the inverse direction of the association between process measures and PPR rates was consistently observed. As for heart failure, none of the composite and individual measures were statistically associated with 30-day, risk-adjusted PPR rates after adjusting for patient clinical and demographical characteristics and hospital characteristics (Table 8).

- Interaction effect

We found no evidence of an interaction effect between condition-specific hospital volume and process quality of inpatient care for any of the three conditions.

CHAPTER V: DISCUSSION

The present work examined the association between process quality of inpatient care and condition-specific risk-adjusted 30-day PPR rates (Research Question 1), and found that better performance on the process quality metrics was associated with the better patient outcome (i.e., low PPR rates) in pneumonia, but not generally in two cardiovascular conditions (i.e., heart failure and acute myocardial infarction). Hospitals with better performance for process quality measures had lower condition-specific 30-day PPR rates for pneumonia, even after taking patient risk factors and hospital characteristics into account ($p<0.05$ for 5 out of 9 process quality measures and $p<0.10$ for 3 out of 9 measures). These findings are consistent with the results of previous studies that examined the association between quality of inpatient care and mortality rates at hospital level [21, 22]. However, we did not find a similar inverse pattern for heart failure and acute myocardial infarction. While we observed, in the case of acute myocardial infarction, a statistically significant inverse association in one individual measure (i.e., PCI within 90m of arrival) and a marginally significant inverse trend in one composite measure (i.e., admission composite measure), none of the process quality measures for heart failure were found to be associated with condition-specific 30-day PPR rates. Our findings of disassociation between heart failure process quality metrics and 30-day PPR rates are consistent with findings from previous OPTIMIZE-HF studies investigating the association between process quality measures for heart failure and cardiovascular readmissions [74, 75].

We also investigated whether the influence of process quality of inpatient care on potentially preventable readmission rates contingent on hospital condition-specific volume (Research Question 2), but found no evidence of an interaction effect for all three conditions.

There are possible reasons why the findings in cardiovascular conditions are dissimilar from those in pneumonia. One hypothesis is that there was not enough variation in the cardiovascular measures of quality of inpatient care across hospitals for the present work to detect their significant associations with 30-day PPR rates. For example, "PCI within 90 minutes of arrival" exhibited the lowest performance score with the largest variation among process quality measures for acute myocardial infarction, and among measures in acute myocardial infarction, it was the only significant measure that was inversely related to 30-day PPR rates. While plausible, this hypothesis alone may not perfectly explicate the disassociations between process quality metrics and 30-day PPR rates because variations in the process quality measures for pneumonia were not substantially large, compared to those in the process measures for cardiovascular conditions. In addition to little variations in the cardiovascular process measures, variance is relatively smaller in cardiovascular conditions compared to pneumonia. Variance between hospitals in unconditional models for heart failure ranged from 0.029 to 0.030, for acute myocardial infarction ranged from 0.023 to 0.040, and for pneumonia ranged from 0.105 to 0.113.

Another hypothesis is that cardiovascular process quality metrics selected for the present study may indeed not be related with 30-day PPR rates. Cardiovascular process

quality metrics employed in this study capture only incomplete information on hospitals' adherence. For example, five out of six AMI individual process quality measures are medication-related, such as beta-blocker, aspirin, and ACE Inhibitor. Information about whether a hospital prescribed a drug (e.g., beta blocker) in aggregate only does not capture other important information about whether the appropriate dose was used, about whether appropriately prescribed a drug considering all of the types of unwanted medication reaction [86], or about whether patients adhered to medication instructions after discharge. Those missing information for which current process metrics cannot capture might have associations with 30-day PPR rates.

Lastly, 30 days might be too short to observe the association of the medications, particularly beta-blockers, with PPR rates. One systemic review of randomized controlled trials on beta blocker in the treatment for AMI found that short-term use (less than 1 year) of blockade after acute myocardial infarction may not have as large benefits as does long-term use (more than 1 year) [87]. This finding suggests that a longer readmission time-frame would be more suitable to detect link between beta-blockers and PPR rates, but, paradoxically, a longer readmission time-frame (> 90 days) reflects the effectiveness of community-based, monitoring and maintenance systems [4]. This study adopted a readmission time interval of 30-day because hospitals may have greater control over the clinical processes during the hospitalization and the discharge process.

Findings from the present study have implications for payers, providers, and future research on readmission. This study identified risk factors for 30-day PPR among patients with heart failure, acute myocardial infarction, and pneumonia. If readmission

becomes a part of an incentive program, hospitals may choose to focus their scarce resources on this subset of patients at high risks of potentially preventable readmissions. More importantly, our findings at hospital-level suggest that 30-day PPR rates in pneumonia might be reduced by hospitals' efforts to better adhere to the recommended care. This study also has an important implication to future health service research on readmission. While a complex set of factors may contribute to occurrence of preventable readmissions, most theoretical and empirical attention has been paid to the patient-level factors, including demographics, socioeconomic standing, behaviors, and disease states. The future research on potentially preventable readmissions might need to account for the quality of inpatient care provided to the patients during index hospitalization as well.

Better adherence to the process quality metrics for cardiovascular conditions currently in use by CMS may not lead to low 30-day PPR rates. While we found an inverse association between process quality metrics currently in use by CMS for pneumonia and 30-day PPR rates, that was not the case for cardiovascular conditions. Performance for current clinical process quality metrics for pneumonia might be able to be considered as a potential indicator of 30-day PPR rates, but not for heart failure and acute myocardial infarction. Performance measures should be confined to those clinical process of care for which the evidence is so robust that successful adherence to them increases the likelihood of optimal patient outcomes [88, 89]. Policy implications emerge from the present study. First, if a policy objective is to reduce 30-day PPR rates for heart failure and acute myocardial infarction through enhancing hospital performance

for process quality of care, more evidence-based process quality metrics closely linked to 30-day PPR rates needs to be developed. Second, one size does not fit all. As evidenced in this study, both the existence of an association and the magnitude of association between process and outcome are different for each condition. Before implementing pay-for-performance broadly across all condition, policy makers need to confirm a causative association between process care metrics and patient outcomes for each condition.

Our findings should be interpreted with caution as this study has several limitations. First, there have been no empirical studies validating the PPR algorithm. In developing PPR logic, clinical panels applied criteria for clinical relevance and preventability. The PPR algorithm needs validation studies assessing reproducibility and reliability of the judgment process. However, as mentioned earlier, the methodologies are being used in several state agencies, including New York, Florida, Texas, Massachusetts, Colorado, and Hawaii. Second, risk-adjustment method used in this study has an inherent limitation in that it is only able to adjust to the extent that clinical information about the patient is captured by administrative data. Administrative data sets have been criticized as lacking clinical detail, such as diagnostic and prognostic information, required to permit adequate adjustment for each patient's underlying medical condition[90-94]. Although we used a well-validated risk-adjustment model designed for use with administrative data [95, 96], the findings should be interpreted with cautions. Third, this work used a hospital discharge dataset that may contain misclassification of the variables due to coding errors in ICD-9-CM codes. Fourth, the findings from this

study are limited in the reliance on the cross-sectional observational data which does not allow us to investigate a causal relationship between performance for process quality and 30-day PPR rates. It is possible that the observed association between process quality of inpatient care and 30-day PPR rates is confounded by patient or hospital factors that are not observed in our data. More information about the patients and hospitals is needed to clarify whether the association reflects a causal relationship. Fifth, because sample hospitals are located in California and Florida, our findings may not generalize to other geographic areas. Similarly, as we focused only on three medical conditions, our findings may not be generalized to other medical and surgical conditions. Finally, it is unclear how accurate hospitals' process quality performance is. Hospitals self-report their process quality performance and hence, it is likely that there is a systematic scoring bias in hospitals' incomplete reporting across all measures. That is, hospitals might not report specific performance scores if they poorly performed in the particular measure. If it is the case, the association between process quality of inpatient care and 30-day PPR rates may be weaker.

We suggest avenues for future research on the PPR and process quality metrics. The first area of research for the future is to examine whether the findings of this study are generalizable at the national level. We excluded patients who died during index hospitalization because they are not eligible for readmissions. Consequently, higher in-hospital or post-discharge mortality rates could bias PPR rates because patients who died can no longer be readmitted. A potential consequence of not accounting for the inter-dependence of these two risks is that if a hospital has higher mortality rate, a smaller

proportion of patients are eligible for PPR. Hence, adjusting for the risk of mortality during index hospitalization and post discharge may alter our results. Future studies need to investigate the association between process quality of inpatient care and 30-day PPR controlling for the simultaneous risk of intrahospital mortality and post discharge mortality. The competing risks Cox proportional hazards regression model, controlling for the simultaneous risk of mortality, may be used in future studies. Another area of future research is to examine, with a prospective, longitudinal study design, whether changes in performance for process quality metrics lead to changes in 30-day PPR rates. As discussed, process quality metrics in current use by CMS capture only whether hospitals adhere to a particular recommended procedure in a discrete manner (i.e., success or failure) even if there should be variation in quality of adherence to a particular recommended care. As noted, information about whether a hospital adhered to a recommended process care does not tell much about quality of adherence. Can we assume that the quality of performance for a particular process quality measure among hospitals if they performed equivalently for the measure? Future research needs to explore the degree of heterogeneity of adherence to process quality metrics in equally performing groups although this will necessitate considerable time and resources to investigate. This would make it possible to further differentiate the performance on process care measures that is once seemingly homogeneous. Will our findings be different if a shorter readmission time frame will be chosen? Future research need to investigate whether our findings will be unchanged even with shorter readmission time frame such as 7-days or 15-days. Lastly, future research needs to determine the

association between process quality measures and 30-day PPR rates for other medical conditions and surgical procedures.

Hospitals have a significant stake in identifying strategies that can reduce occurrences of preventable readmissions. The recently enacted health reform legislation introduces a Hospital Readmissions Reduction Program (Section 3025 of the Patient Protection and Affordable Care Act). For fiscal years beginning on or after October 1, 2012, inpatient payments to hospitals will be reduced if a hospital experiences excessive readmissions within a specified period following discharge for a heart attack, heart failure, or pneumonia [97]. The present study revealed the inverse association of process quality of inpatient care with 30-day PPR rates in the case of pneumonia but not cardiovascular conditions. Our work also identified patient risk factors associated with the risk of PPR at patient-level analysis. Findings from this study may be served as useful sources to entities that are seeking ways to reduce the occurrences of PPRs.

Table 1:
Studies investigating a link between performance for process measures and readmissions (or combined readmission and mortality)

Citation	Readmission Conditions & Timeframe	Population & Setting	Data sources	Design & Sample size	Statistical approach	Process measures	Results
Hernandez [74]	Cardiovascular readmission / 60-day & 1-year	HF patients from OPTIMIZE-HF registry	OPTIMIZE-HF registry linked to Medicare claims data	Retrospective cohort / Patients: 20441; Hospitals: 141	Cox proportional hazards model	6 performance measures: 1) Any β-blocker; 2) Evidence-based β-blocker; 3) Warfarin; 4) Aldosterone antagonist; 5) Implantable cardioverter-defibrillator; and 6) Disease management	"Evidence-based β-blocker" was associated with reduced risk of cardiovascular readmission both at 60-day and 1-year.
Patterson [75]	Cardiovascular readmission / 1-year	HF patients from OPTIMIZE-HF registry	OPTIMIZE-HF registry linked to Medicare claims data	Retrospective cohort / Patients: 22750; Hospitals: 150	Cox proportional hazards model	5 performance measures: 1) discharge instruction; 2) Assessment of left ventricular function; 3) prescription of ACE inhibitor or angiotensin receptor blocker at discharge; 4) prescription of beta-blockers at discharge; and 5) smoking cessation counseling	None of the performance measures was associated with reduced risk of cardiovascular readmission both at 1-year.
Fonarow [72]	Combined mortality and all-cause readmission / 60-90 days	HF patients from OPTIMIZE-HF registry	OPTIMIZE-HF registry linked to Medicare claims data	Prospective cohort / Patients: 5791; Hospitals: 91	Cox proportional hazards models for mortality outcome and logistic regression model for the combined measure	5 performance measures: 1) discharge instruction; 2) Assessment of left ventricular function; 3) prescription of ACE inhibitor or angiotensin receptor blocker at discharge; 4) prescription of beta-blockers at discharge; 5) Warfarin for atrial fibrillation; and 6) smoking cessation counseling	"Prescription of ACE inhibitor or angiotensin receptor blocker at discharge" and "beta-blocker at discharge" were associated with reduced risk of combined mortality and readmission at 60- to 90-day.

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Table 2:
Studies (n=4) investigating hospital factors associated with all-cause readmissions

Citation	Readmission Conditions & Timeframe	Population & Setting	Data sources	Design & Sample size	Statistical approach	Hospital factors associated with high readmission rates
Anderson [54]	All-cause / 60-day	Medicare patients (no restriction for the diagnosis of initial admission)	1974-1977 Medicare claims date; AHA Annual Survey of Hospitals (year N.S.)	Cross-sectional / Patients: 270,266; Hospitals: N.S.	N.S.	Non-teaching; With fewer beds
Joynt (2011-a) [11]	All-cause / 30-day	Medicare patients with heart failure	2006-2007 Medicare Provider Analysis Review (MedPAR); 2007 AHA Annual Survey of Hospitals	Cross-sectional / Discharge: 905,764; Hospitals: 4567	Ordinary Least Square model	For-profit and public; without cardiac services and hospitals with partial cardiac services; low nurse staffing; with fewer beds
Joynt (2011-b) [12]	All-cause / 30-day	Medicare patients with heart failure	2006-2007 Medicare Provider Analysis Review (MedPAR); 2007 AHA Annual Survey of Hospitals	Cross-sectional / Discharge: 1,029,497; Hospitals: 4,095	Logistic Regression model	With low-volume for mortality rate but not for readmission rate

Joynt (2011-c) [13]	All-cause / 30-day	Medicare patients with heart failure, acute myocardial infarction, or pneumonia	2006-2008 Medicare Provider Analysis Review (MedPAR); 2007 AHA Annual Survey of Hospitals	Retrospective cohort / Discharge: 3,163,011; Hospitals: 4,560	Logistic Regression model	Minority-serving hospitals

N.S.: Not Specified
AHA: American Hospital Association

Table 3:
Hospital Characteristics

	Heart Failure				**Acute Myocardial Infarction**				**Pneumonia**			
	Low (n=143)	Medium (n=142)	High (n=142)	P Value	Low (n=127)	Medium (n=127)	High (n=126)	P Value	Low (n=142)	Medium (n=142)	High (n=142)	P Value
Crude 30-day PPR Rate	**12.31%**	**16.66%**	**24.69%**		**7.79%**	**15.47%**	**26.72%**		**6.84%**	**11.9%**	**19.77%**	
Ownership				0.017				0.043				0.343
Public	21 (15)	16 (11)	32 (23)		24 (19)	13 (10)	21 (15)		26 (18)	18 (13)	25 (18)	
Private not-for-profit	83 (58)	86 (61)	61 (43)		74 (58)	76 (60)	59 (47)		76 (54)	85 (60)	69 (48)	
Private for-profit	39 (27)	40 (28)	49 (34)		29 (23)	38 (30)	46 (36)		40 (28)	39 (27)	48 (34)	
Cardiac Catherization				0.008				0.000				0.000
No	41 (29)	30 (21)	54 (38)		25 (20)	15 (12)	44 (35)		35 (25)	27 (19)	62 (44)	
Yes	102 (71)	112 (79)	88 (62)		102 (80)	112 (88)	82 (65)		107 (75)	115 (81)	80 (56)	
Teaching intensity (Resident-to-bed ratio)				0.422				0.823				0.678
0 (non-teaching)	110 (77)	102 (72)	95 (67)		86 (68)	90 (71)	89 (70)		107 (75)	98 (69)	101 (71)	
0-0.05 (low intensity)	11 (8)	20 (14)	19 (13)		15 (12)	17 (13)	16 (13)		12 (9)	17 (12)	21 (15)	
0.05-0.6 (medium intensity)	15 (10)	12 (8)	17 (12)		18 (14)	14 (11)	11 (9)		14 (10)	17 (12)	13 (9)	
>0.6 (high intensity)	7 (5)	8 (6)	11 (8)		8 (6)	6 (5)	10 (8)		9 (6)	10 (7)	7 (5)	
Magnet hospitals				0.671				0.461				0.017
Non-Magnet	135 (94)	134 (94)	137 (96)		119 (94)	119 (94)	122 (97)		130 (92)	135 (95)	140 (99)	
Magnet	8 (6)	8 (6)	5 (3.52)		8 (6)	8 (6)	4 (3)		12 (8)	7 (5)	2 (1)	
Volume				0.066				0.000				0.071
1st quartile (smallest)	41 (29)	26 (18)	42 (30)		30 (24)	20 (16)	48 (38)		35 (25)	24 (17)	48 (34)	
2nd quartile	32 (22)	37 (26)	36 (25)		32 (25)	21 (17)	41 (32)		35 (25)	37 (26)	34 (24)	
3rd quartile	36 (25)	33 (23)	39 (27)		37 (29)	32 (25)	25 (20)		37 (26)	39 (27)	31 (22)	
4th quartile (largest)	34 (24)	46 (33)	25 (18)		28 (22)	54 (42)	12 (10)		35 (25)	42 (30)	29 (20)	
System affiliation				0.111				0.859				0.462
System hospital	46 (32)	30 (21)	38 (27)		33 (26)	31 (24)	29 (23)		36 (25)	34 (24)	43 (30)	
Non-system hospital	97 (68)	112 (79)	104 (73)		94 (74)	96 (76)	97 (77)		106 (75)	108 (76)	99 (70)	
Metropolitan Statistical Area				0.001				0.022				0.001
Rural	9 (6)	6 (4)	14 (10)		2 (2)	5 (4)	13 (10)		8 (6)	11 (8)	11 (8)	
Micro/Division	39 (27)	53 (37)	68 (48)		51 (40)	46 (36)	52 (41)		43 (30)	44 (31)	73 (51)	

Metro	95 (67)	83 (59)	60 (42)		74 (58)	76 (60)	61 (48)		91 (64)	87 (61)	58 (41)	
State				0.853				0.008				0.000
California	89 (62)	91 (64)	93 (65)		91 (72)	67 (53)	79 (63)		80 (56)	81 (57)	112 (79)	
Florida	54 (38)	51 (36)	49 (35)		36 (28)	60 (47)	47 (37)		62 (44)	61 (43)	30 (21)	
DSH Index				0.048				0.301				0.049
1st thirtiles (low)	50 (35)	45 (32)	48 (34)		50 (39)	41 (32)	36 (29)		53 (37)	41 (29)	48 (34)	
2nd thirtiles	53 (37)	54 (38)	35 (25)		43 (34)	42 (33)	42 (33)		46 (33)	59 (41)	37 (26)	
3rd thirtiles (high)	40 (28)	43 (30)	59 (41)		34 (27)	44 (35)	48 (38)		43 (30)	42 (30)	57 (40)	
Number of comorbidity				0.249				0.262				0.096
1st thirtiles (low)	55 (38)	43 (30)	45 (32)		50 (39)	38 (30)	39 (31)		50 (35)	38 (27)	54 (38)	
2nd thirtiles	43 (30)	56 (40)	43 (30)		41 (32)	48 (38)	38 (30)		51 (36)	54 (38)	37 (26)	
3rd thirtiles (high)	45 (32)	43 (30)	54 (38)		36 (28)	41 (32)	49 (39)		41 (29)	50 (35)	51 (36)	
Proportion of patients with prior hospitalization for both HF and other conditions				0.538				0.000				0.000
1st thirtiles (low)	51 (36)	49 (34)	43 (30)		46 (36)	28 (22)	53 (42)		62 (44)	51 (36)	29 (20)	
2nd thirtiles	46 (32)	52 (37)	45 (32)		42 (33)	61 (48)	24 (19)		47 (33)	54 (38)	41 (29)	
3rd thirtiles (high)	46 (32)	41 (29)	54 (38)		39 (31)	38 (30)	49 (39)		33 (23)	37 (26)	72 (51)	

Table 4:
Summary of Hospital Performance for Condition-Specific Process Quality Measures

	Hospital, No	Overall [Mean (SD)]	Hospitals in the top 25% (4th quartile) [Mean (SD)]	Hospitals in the middle 50% (2nd & 3rd quartile) [Mean (SD)]	Hospitals in the low 25% (1st quartile) [Mean (SD)]
Heart Failure					
ACE Inhibitor or ARB for LVSD [d]	396	87.27 (9.80)	97.94 (1.51)	89.47 (3.70)	74.58 (8.15)
Evaluation of LVS Function [d]	425	70.31 (23.90)	95.62 (3.25)	74.71 (8.33)	36.88 (17.95)
Discharge Instructions [d]	426	91.10 (14.16)	99.40 (0.49)	95.28 (2.20)	75.79 (21.05)
- *HF Discharge Composite score* [d]	427	82.17 (15.46)	95.99 (2.17)	85.57 (4.36)	61.66 (16.67)
Acute Myocardial Infarction					
ACE Inhibitor or ARB for LVSD [d]	222	89.36 (8.75)	99.59 (0.76)	91.50 (3.63)	78.11 (6.29)
Aspirin at Arrival [a]	379	96.39 (4.11)	99.21 (0.87) †	96.56 (0.49) ‡	91.31 (4.32)
Aspirin at Discharge [d]	339	93.91 (8.02)	100 (0)	96.62 (1.85)	83.31 (9.61)
Beta Blocker at Arrival [a]	369	92.78 (7.15)	99.64 (0.48)	94.91 (2.24)	83.20 (7.20)
Beta Blocker at Discharge [d]	343	94.39 (7.36)	100 (0)	96.95 (1.56)	86.19 (9.21)
PCI Within 90m of Arrival [a]	168	66.05 (19.53)	87.89 (4.59)	70.01 (8.23)	38.43 (12.00)
- *AMI Admission Composite score* [a]	380	93.27 (5.36)	98.57 (1.04)	94.16 (1.91)	86.22 (5.20)
- *AMI Discharge Composite score* [d]	345	93.63 (7.37)	99.42 (0.57)	95.48 (1.76)	84.25 (9.04)
- *AMI Composite score*	370	93.83 (5.28)	98.74 (0.81)	94.81 (1.65)	87.04 (5.77)
Pneumonia					
Assessed and Given Influenza Vaccination [d]	411	70.13 (23.31)	94.05 (3.49)	75.36 (8.56)	37.98 (18.43)
Assessed and Given Pneumococcal Vaccination [d]	424	75.22 (20.59)	94.74 (2.62)	80.53 (6.74)	46.77 (18.79)
Initial Antibiotic(s) within 6h After Arrival [a]	394	92.49 (7.20)	99.22 (0.88)	94.45 (1.98)	84.01 (7.65)
Oxygenation Assessment [a]	426	99.72 (1.60)	-	-	-
The Most Appropriate Initial Antibiotic(s) [a]	422	88.00 (8.12)	95.69 (1.69)	89.60 (2.39)	78.35 (8.90)
Initial ER Blood Culture Performed prior to First Hospital Dose of Antibiotics [a]	415	88.89 (6.95)	96.20 (1.35)	90.78 (2.23)	80.04 (6.03)
- *PN Admission Composite score* [a]	426	93.37 (3.75)	97.15 (1.02)	93.94 (1.16)	88.48 (3.69)
- *PN Discharge Composite score* [d]	424	73.72 (20.78)	93.55 (3.25)	78.37 (6.93)	44.61 (18.35)
- *PN Composite score*	425	87.71 (7.97)	95.41 (1.65)	89.23 (2.44)	77.08 (7.86)

To ensure the stability of the measures, hospitals with fewer than 15 patients in the denominator of a measure are excluded. A composite score for a condition is calculated only if that hospital treated at least 15 patients for one of the process measures for that condition. If a hospital did not treat at least 15 patients in any one indicator, then no composite score was calculated. For that reason, the number of hospitals' composite measures do not equal to the number of individual measure.
†: hospitals in the 3rd and 4th quartiles;
‡: hospitals in the 2nd quartile

Table 5:
Summary of Within-Hospital (Level 1) Model of Heart Failure PPR†

	M_HF1: ACE Inhibitor or ARB for LVSD	M_HF2: Evaluation of LVS Function	M_HF3: Discharge Instructions	M_HFCD: Discharge Composite score
	aOR	aOR	aOR	aOR
Socio-Demographic & Post-discharge				
Age	1.005*	1.006**	1.006**	1.006**
Female	*NSS*	*NSS*	*NSS*	*NSS*
Race (Ref: White)				
Black	*NSS*	*NSS*	*NSS*	*NSS*
Hispanic	*NSS*	1.098*	1.096*	1.096*
Others	*NSS*	*NSS*	*NSS*	*NSS*
Disposition (Ref=Routine)				
Home Health Care	1.175***	1.174***	1.174***	1.174***
Nursing Home	1.575***	1.572***	1.575***	1.575***
Median Income Quartile (Ref=1st quartile: Poorest)				
2nd quartile	*NSS*	*NSS*	*NSS*	*NSS*
3rd quartile	*NSS*	*NSS*	*NSS*	*NSS*
4th quartile	*NSS*	*NSS*	*NSS*	*NSS*
Severity				
Prior admission (1y) (Ref=No)				
Prior admission (1y) other than heart failure	1.263*	1.237*	1.236*	1.236*
Prior admission (1y) for heart failure	1.355***	1.356***	1.356***	1.356***
Prior admission (1y) for both heart failure and other conditions	1.830***	1.831***	1.831***	1.831***
Comorbidities				
AIDS	4.828*	4.873*	4.842*	4.869*
Alcohol abuse	*NSS*	*NSS*	*NSS*	*NSS*
Deficiency anemias	1.084**	1.079*	1.079*	1.080*
Rheumatoid arthritis	*NSS*	*NSS*	*NSS*	*NSS*

Chronic blood loss anemia	*NSS*	*NSS*	*NSS*	*NSS*
Chronic pulmonary disease	1.105***	1.106***	1.107***	1.107***
Coagulopathy	*NSS*	*NSS*	*NSS*	*NSS*
Depression	*NSS*	*NSS*	*NSS*	*NSS*
Diabetes, uncomplicated	*NSS*	*NSS*	*NSS*	*NSS*
Diabetes w/ chronic complications	1.170**	1.166**	1.166**	1.166**
Drug abuse	*NSS*	*NSS*	*NSS*	*NSS*
Hypertension	*NSS*	*NSS*	*NSS*	*NSS*
Hypothyroidism	*NSS*	*NSS*	*NSS*	*NSS*
Liver disease	*NSS*	*NSS*	*NSS*	*NSS*
Lymphoma	*NSS*	*NSS*	*NSS*	*NSS*
Fluid and electrolyte disorders	1.097**	1.098**	1.098**	1.098**
Metastatic cancer	*NSS*	*NSS*	*NSS*	*NSS*
Other neurological disorders	*NSS*	*NSS*	*NSS*	*NSS*
Obesity	*NSS*	*NSS*	*NSS*	*NSS*
Paralysis	*NSS*	*NSS*	*NSS*	*NSS*
Peripheral vascular disorders	1.172***	1.165***	1.164***	1.165***
Psychoses	1.223*	1.217*	1.216*	1.216*
Pulmonary circulation disorders	*NSS*	*NSS*	*NSS*	*NSS*
Renal failure	1.239***	1.241***	1.241***	1.241***
Solid tumor without metastasis	*NSS*	*NSS*	*NSS*	*NSS*
Peptic ulcer disease	*NSS*	*NSS*	*NSS*	*NSS*
Valvular disease	*NSS*	*NSS*	*NSS*	*NSS*
Weight loss	*NSS*	*NSS*	*NSS*	*NSS*

NSS: Not statistically significant
aOR: Adjusted Odds Ratio
†: Full results are presented in Appendix Tables 1 to 4

Table 6:
Summary of Within-Hospital (Level 1) Model of Acute Myocardial Infarction PPR†

	M_HA1: ACE Inhibitor or ARB for LVSD	M_HA2: Aspirin at Arrival	M_HA3: Aspirin at Discharge	M_HA4: Beta Blocker at Arrival	M_HA5: Beta Blocker at Discharge	M_HA7: PCI Within 90m of Arrival
	aOR	aOR	aOR	aOR	aOR	aOR
Socio-Demographic & Post-discharge						
Age	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Female	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Race (Ref: White)						
Black	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Hispanic	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Others	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Disposition (Ref=Routine)						
Home Health Care	1.342***	1.304***	1.312***	1.301***	1.310***	1.407***
Nursing Home	1.868***	1.879***	1.879***	1.868***	1.873***	1.985***
Median Income Quartile (Ref=1st quartile: Poorest)						
2nd quartile	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
3rd quartile	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
4th quartile	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Severity						
Prior admission (1y) (Ref=No)						
Prior admission (1y) other than AMI	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	-
Prior admission (1y) for AMI	1.377***	1.352***	1.357***	1.354***	1.360***	1.407***
Prior admission (1y) for both AMI and other conditions	1.473***	1.476***	1.499***	1.471***	1.500***	1.985***
AMI location: Anterior	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
AMI location: Other	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Procedure						
CABG	0.782**	0.773***	0.776**	0.771***	0.777**	0.778**

PTCA	1.136*	1.124*	1.124*	1.121*	1.123*	1.138*
Comorbidities						
AIDS	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	-
Alcohol abuse	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Deficiency anemias	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Rheumatoid arthritis	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Chronic blood loss anemia	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Congest Heart Failure	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Chronic pulmonary disease	1.174***	1.185***	1.184***	1.191***	1.182***	1.165**
Coagulopathy	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Depression	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Diabetes, uncomplicated	1.159**	1.155**	1.152**	1.153**	1.152**	1.168**
Diabetes w/ chronic complications	1.229*	1.264**	1.272**	1.262**	1.264**	1.283**
Drug abuse	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Hypertension	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Hypothyroidism	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Liver disease	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Lymphoma	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Fluid and electrolyte disorders	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Metastatic cancer	0.231*	0.277*	0.303*	0.286*	0.293*	*NSS*
Other neurological disorders	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Obesity	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Paralysis	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Peripheral vascular disorders	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Psychoses	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Pulmonary circulation disorders	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Renal failure	1.196***	1.208***	1.202***	1.212***	1.207***	1.181**
Solid tumor without metastasis	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Peptic ulcer disease	*NSS*	*NSS*	4.744*	4.735*	4.737*	*NSS*
Valvular disease	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Weight loss	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*

NSS: Not statistically significant
aOR: Adjusted Odds Ratio
†: Full results are presented in Appendix Tables 5 to 13

Table 6:
Summary of Within-Hospital (Level 1) Model of Acute Myocardial Infarction PPR (Cont'd)

	M_HACA: Admission Composite	M_HACD: Discharge Composite	M_HACOMP: Global Composite
	aOR	aOR	aOR
Socio-Demographic & Post-discharge			
Age	*NSS*	*NSS*	*NSS*
Female	*NSS*	*NSS*	*NSS*
Race (Ref: White)			
Black	*NSS*	*NSS*	*NSS*
Hispanic	*NSS*	*NSS*	*NSS*
Others	*NSS*	*NSS*	*NSS*
Disposition (Ref=Routine)			
Home Health Care	1.304***	1.313***	1.303***
Nursing Home	1.882***	1.871***	1.870***
Median Income Quartile (Ref=1st quartile: Poorest)			
2nd quartile	*NSS*	*NSS*	*NSS*
3rd quartile	*NSS*	*NSS*	*NSS*
4th quartile	*NSS*	*NSS*	*NSS*
Severity			
Prior admission (1y) (Ref=No)			
Prior admission (1y) other than AMI	*NSS*	*NSS*	*NSS*
Prior admission (1y) for AMI	1.352***	1.357***	1.355***
Prior admission (1y) for both AMI and other conditions	1.475***	1.499***	1.481***
AMI location: Anterior	*NSS*	*NSS*	*NSS*
AMI location: Other	*NSS*	*NSS*	*NSS*
Procedure			
CABG	0.770***	0.776**	0.777**
PTCA	1.120*	1.123*	1.119*

Comorbidities			
AIDS	*NSS*	*NSS*	*NSS*
Alcohol abuse	*NSS*	*NSS*	*NSS*
Deficiency anemias	*NSS*	*NSS*	*NSS*
Rheumatoid arthritis	*NSS*	*NSS*	*NSS*
Chronic blood loss anemia	*NSS*	*NSS*	*NSS*
Congest Heart Failure	*NSS*	*NSS*	*NSS*
Chronic pulmonary disease	1.186***	1.185***	1.188***
Coagulopathy	*NSS*	*NSS*	*NSS*
Depression	*NSS*	*NSS*	*NSS*
Diabetes, uncomplicated	1.154**	1.153**	1.152**
Diabetes w/ chronic complications	1.265**	1.268**	1.259**
Drug abuse	*NSS*	*NSS*	*NSS*
Hypertension	*NSS*	*NSS*	*NSS*
Hypothyroidism	*NSS*	*NSS*	*NSS*
Liver disease	*NSS*	*NSS*	*NSS*
Lymphoma	*NSS*	*NSS*	*NSS*
Fluid and electrolyte disorders	*NSS*	*NSS*	*NSS*
Metastatic cancer	0.278*	0.293*	0.282*
Other neurological disorders	*NSS*	*NSS*	*NSS*
Obesity	*NSS*	*NSS*	*NSS*
Paralysis	*NSS*	*NSS*	*NSS*
Peripheral vascular disorders	*NSS*	*NSS*	*NSS*
Psychoses	*NSS*	*NSS*	*NSS*
Pulmonary circulation disorders	*NSS*	*NSS*	*NSS*
Renal failure	1.209***	1.199***	1.211***
Solid tumor without metastasis	*NSS*	*NSS*	*NSS*
Peptic ulcer disease	*NSS*	4.736*	4.701*
Valvular disease	*NSS*	*NSS*	*NSS*
Weight loss	*NSS*	*NSS*	*NSS*

NSS: Not statistically significant
aOR: Adjusted Odds Ratio
†: Full results are presented in Appendix Tables 5 to 13

Table 7:
Summary of Within-Hospital (Level 1) Model of Pneumonia PPR

	M_PN1: Assessed & Given Influenza Vaccination	M_PN2: Assessed & Given Pneumococcal Vaccination	M_PN2: Initial Antibiotic(s) within 6h After Arrival	M_PN4: Oxygenation Assessment	M_PN5: the Most Appropriate Initial Antibiotic(s)	M_PN7: Initial ER Blood Culture Performed Prior To First Hospital Dose Of Antibiotics
Socio-Demographic & Post-discharge						
Age	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Female	0.876***	0.877***	0.882***	0.877***	0.875***	0.878***
Race (Ref: White)						
Black	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Hispanic	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Others	0.856*	0.861*	*NSS*	0.863*	0.863*	0.862*
Disposition (Ref=Routine)						
Home Health Care	1.355***	1.346***	1.359***	1.345***	1.350***	1.338***
Nursing Home	2.139***	2.128***	2.134***	2.124***	2.129***	2.110***
Median Income Quartile (Ref=1st quartile: Poorest)						
2nd quartile	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
3rd quartile	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
4th quartile	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Severity						
Prior admission (1y) (Ref=No)						
Prior admission (1y) other than PN	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Prior admission (1y) for PN	1.435***	1.440***	1.421***	1.441***	1.438***	1.439***
Prior admission (1y) for both PN and other conditions	1.859***	1.857***	1.854***	1.852***	1.857***	1.853***
Comorbidities						
Alcohol abuse	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Deficiency anemias	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Rheumatoid arthritis	1.267**	1.266**	1.262**	1.266**	1.269**	1.268**
Chronic blood loss anemia	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*

Congest Heart Failure	1.206***	1.211***	1.212***	1.210***	1.208***	1.215***
Chronic pulmonary disease	1.191***	1.188***	1.195***	1.187***	1.192***	1.193***
Coagulopathy	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Depression	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Diabetes, uncomplicated	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Diabetes w/ chronic complications	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Drug abuse	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Hypertension	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Hypothyroidism	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Liver disease	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Lymphoma	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Fluid and electrolyte disorders	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Metastatic cancer	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Other neurological disorders	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Obesity	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Paralysis	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Peripheral vascular disorders	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Psychoses	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Pulmonary circulation disorders	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Renal failure	1.138**	1.133**	1.132**	1.131**	1.139**	1.132**
Solid tumor without metastasis	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Peptic ulcer disease	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Valvular disease	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*	*NSS*
Weight loss	1.178*	1.184*	1.161*	1.190*	1.180*	1.184*

NSS: Not statistically significant
aOR: Adjusted Odds Ratio
†: Full results are presented in Tables 14 to 22

Table 7:
Summary of Within-Hospital (Level 1) Model of Pneumonia PPR (Cont'd)

	M_PNCA: Admission Composite	M_PNCD: Discharge Composite	M_PNCOMP: Global Composite
	aOR	aOR	aOR
Socio-Demographic & Post-discharge			
Age	*NSS*	*NSS*	*NSS*
Female	0.876***	0.877***	0.877***
Race (Ref: White)			
Black	*NSS*	*NSS*	*NSS*
Hispanic	*NSS*	*NSS*	*NSS*
Others	0.864*	0.856*	0.861*
Disposition (Ref=Routine)			
Home Health Care	1.347***	1.346***	1.348***
Nursing Home	2.125***	2.128***	2.126***
Median Income Quartile (Ref=1st quartile: Poorest)			
2nd quartile	*NSS*	*NSS*	*NSS*
3rd quartile	*NSS*	*NSS*	*NSS*
4th quartile	*NSS*	*NSS*	*NSS*
Severity			
Prior admission (1y) (Ref=No)			
Prior admission (1y) other than PN	*NSS*	*NSS*	*NSS*
Prior admission (1y) for PN	1.441***	1.440***	1.441***
Prior admission (1y) for both PN and other conditions	1.853***	1.857***	1.856***
Comorbidities			
Alcohol abuse	*NSS*	*NSS*	*NSS*
Deficiency anemias	*NSS*	*NSS*	*NSS*
Rheumatoid arthritis	1.268**	1.266**	1.267**
Chronic blood loss anemia	*NSS*	*NSS*	*NSS*
Congest Heart Failure	1.209***	1.211***	1.212***
Chronic pulmonary disease	1.187***	1.188***	1.187***

Coagulopathy	*NSS*	*NSS*	*NSS*
Depression	*NSS*	*NSS*	*NSS*
Diabetes, uncomplicated	*NSS*	*NSS*	*NSS*
Diabetes w/ chronic complications	*NSS*	*NSS*	*NSS*
Drug abuse	*NSS*	*NSS*	*NSS*
Hypertension	*NSS*	*NSS*	*NSS*
Hypothyroidism	*NSS*	*NSS*	*NSS*
Liver disease	*NSS*	*NSS*	*NSS*
Lymphoma	*NSS*	*NSS*	*NSS*
Fluid and electrolyte disorders	*NSS*	*NSS*	*NSS*
Metastatic cancer	*NSS*	*NSS*	*NSS*
Other neurological disorders	*NSS*	*NSS*	*NSS*
Obesity	*NSS*	*NSS*	*NSS*
Paralysis	*NSS*	*NSS*	*NSS*
Peripheral vascular disorders	*NSS*	*NSS*	*NSS*
Psychoses	*NSS*	*NSS*	*NSS*
Pulmonary circulation disorders	*NSS*	*NSS*	*NSS*
Renal failure	1.133**	1.133**	1.133**
Solid tumor without metastasis	*NSS*	*NSS*	*NSS*
Peptic ulcer disease	*NSS*	*NSS*	*NSS*
Valvular disease	*NSS*	*NSS*	*NSS*
Weight loss	1.187*	1.184*	1.182*

NSS: Not statistically significant
aOR: Adjusted Odds Ratio
†: Full results are presented in Table 14 to 22

Table 8:
Summary of Association between Process Quality Measures and Heart Failure PPR using Hierarchical Logistic Regression†

	Heart Failure 30-day PPR rates		
	Coefficient	Standard Error	Odds Ratio
Discharge Composite Score	-0.000	0.002	1.000
n: level-1 (patients) = 42051			
n: level-2 (hospitals) = 427			
ACE Inhibitor or ARB for LVSD	0.001	0.002	1.001
n: level-1 (patients) = 41323			
n: level-2 (hospitals) = 396			
Evaluation of LVS Function	-0.000	0.001	1.000
n: level-1 (patients) = 42038			
n: level-2 (hospitals) = 425			
Discharge Instructions	0.001	0.002	1.001
n: level-1 (patients) = 42044			
n: level-2 (hospitals) = 426			

†: Multivariable analysis adjusted for 1) patient level variables (level 1), including age, sex, race/ethnicity, discharge destination, severity measured by prior hospitalization, and Elixhauser comorbid conditions, and 2) hospital level variables (level 2), including hospital ownership status, whether a hospital perform cardiac catherization, Magnet status, system affiliation, teaching intensity, and mean number of comorbid conditions, proportion of patients with prior history of hospitalization for both HF and other conditions, condition-specific hospital volume, DSH index, and State.
Full results are presented in Appendix Tables 1 to 4
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 9:
Summary of Association between Process Quality Measures and Acute Myocardial Infarction PPR using Hierarchical Logistic Regression†

	Coef.	Std. Err.	P-value	OR
Admission Composite Score	-0.010~	0.006	0.085	0.990~
n: level-1 (patients) = 21635				
n: level-2 (hospitals) = 380				
Discharge Composite Score	-0.004	0.005	0.464	0.996
n: level-1 (patients) = 21367				
n: level-2 (hospitals) = 346				
Global Composite Score	-0.008	0.006	0.204	0.992
n: level-1 (patients) = 21580				
n: level-2 (hospitals) = 371				
ACE Inhibitor or ARB for LVSD	-0.001	0.003	0.726	0.999
n: level-1 (patients) = 19086				
n: level-2 (hospitals) = 222				
Aspirin at Arrival	-0.010	0.008	0.202	0.990
n: level-1 (patients) = 21628				
n: level-2 (hospitals) = 379				
Aspirin at Discharge	-0.003	0.005	0.533	0.997
n: level-1 (patients) = 21301				
n: level-2 (hospitals) = 340				
Beta Blocker at Arrival	-0.001	0.004	0.725	0.999
n: level-1 (patients) = 21548				
n: level-2 (hospitals) = 369				
Beta Blocker at Discharge	-0.003	0.005	0.533	0.997
n: level-1 (patients) = 21328				
n: level-2 (hospitals) = 344				
PCI Within 90m of Arrival	**-0.004****	**0.001**	**0.012**	**0.996****
n: level-1 (patients) = 16654				
n: level-2 (hospitals) = 168				

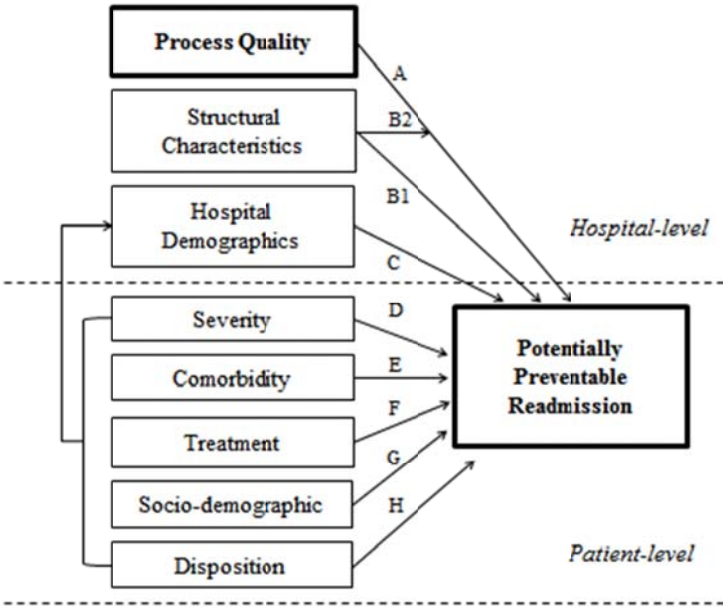
†: Multivariable analysis adjusted for 1) patient level variables (level 1), including age, sex, race/ethnicity, discharge destination, severity measured by prior hospitalization, and Elixhauser comorbid conditions, and 2) hospital level variables (level 2), including hospital ownership status, whether a hospital perform cardiac catherization, Magnet status, system affiliation, teaching intensity, and mean number of comorbid conditions, proportion of patients with prior history of hospitalization for both AMI and other conditions, AMI location condition-specific hospital volume, DSH index, and State.
Full results are presented in Appendix Tables 5 to 13.
~ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 10:
Summary of Association between Pneumonia PPR and Process Quality Measures using Hierarchical Logistic Regression†

	Coef.	Std. Err.	P-value	OR
Admission Composite Score	-0.020**	0.007	0.004	0.980**
n: level-1 (patients) = 36384				
n: level-2 (hospitals) = 426				
Discharge Composite Score	-0.002*	0.001	0.048	0.998*
n: level-1 (patients) = 36374				
n: level-2 (hospitals) = 424				
Global Composite Score	-0.008*	0.003	0.010	0.992*
n: level-1 (patients) = 36378				
n: level-2 (hospitals) = 425				
Assessed and Given Influenza Vaccination	-0.003*	0.001	0.017	0.997*
n: level-1 (patients) = 35964				
n: level-2 (hospitals) = 411				
Assessed and Given Pneumococcal Vaccination	-0.002~	0.001	0.078	0.998
n: level-1 (patients) = 36374				
n: level-2 (hospitals) = 424				
Initial Antibiotic(s) within 6h After Arrival	-0.007~	0.004	0.050	0.993
n: level-1 (patients) = 35202				
n: level-2 (hospitals) = 394				
Oxygenation Assessment	-0.033~	0.017	0.052	0.967
n: level-1 (patients) = 36384				
n: level-2 (hospitals) = 426				
the Most Appropriate Initial Antibiotic(s)	-0.008**	0.003	0.005	0.992**
n: level-1 (patients) = 36172				
n: level-2 (hospitals) = 422				
Initial ER Blood Culture Performed Prior To First Hospital Dose Of Antibiotics	-0.005	0.004	0.134	0.995
n: level-1 (patients) = 36118				
n: level-2 (hospitals) = 415				

†: Multivariable analysis adjusted for 1) patient level variables (level 1), including age, sex, race/ethnicity, discharge destination, severity measured by prior hospitalization, and Elixhauser comorbid conditions, and 2) hospital level variables (level 2), including hospital ownership status, whether a hospital perform cardiac catherization, Magnet status, system affiliation, teaching intensity, and mean number of comorbid conditions, proportion of patients with prior history of hospitalization for both PN and other conditions, condition-specific hospital volume, DSH index, and State.
Full results are presented in Tables 14 to 22
~ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure 1:
Conceptual Framework for Process Quality and Potentially Preventable Readmission



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APPENDICES

Appendix Table 1:
Association of HF-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (Discharge Composite Measure)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.005*	0.002	1.006**	0.006**	0.002	1.006**	0.006**	0.002	1.006**
Female			-0.021	0.029	0.981	-0.025	0.028	0.975	-0.025	0.028	0.975
Race (Ref: White)											
Black			0.082	0.052	1.085	0.064	0.052	1.066	0.065	0.052	1.067
Hispanic			0.131**	0.045	1.140**	0.092*	0.046	1.096*	0.092*	0.046	1.096*
Others			-0.039	0.060	0.962	-0.088	0.062	0.916	-0.087	0.062	0.916
Disposition (Ref=Routine)											
Home Health Care			0.149***	0.036	1.161***	0.160***	0.036	1.174***	0.160***	0.036	1.174***
Nursing Home			0.450***	0.034	1.568***	0.454***	0.034	1.575***	0.454***	0.034	1.574***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.066	0.038	0.936	-0.049	0.038	0.952	-0.049	0.038	0.952
3rd quartile			0.007	0.039	1.007	0.031	0.039	1.031	0.031	0.039	1.032
4th quartile			-0.015	0.042	0.985	0.006	0.044	1.006	0.009	0.044	1.009
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than heart failure			0.210*	0.095	1.234*	0.212*	0.095	1.236*	0.212*	0.095	1.237*
Prior admission (1y) for heart failure			0.304***	0.031	1.355***	0.304***	0.031	1.356***	0.304***	0.031	1.356***
Prior admission (1y) for both heart failure and other			0.605***	0.037	1.832***	0.605***	0.037	1.831***	0.605***	0.037	1.831***

conditions											
Comorbidities											
AIDS			1.562*	0.772	4.768*	1.583*	0.770	4.869*	1.586*	0.770	4.883*
Alcohol abuse			-0.006	0.119	0.994	-0.016	0.119	0.984	-0.016	0.119	0.984
Deficiency anemias			0.076*	0.030	1.079*	0.077*	0.030	1.080*	0.077*	0.030	1.080*
Rheumatoid arthritis			0.089	0.084	1.093	0.098	0.084	1.103	0.098	0.084	1.103
Chronic blood loss anemia			0.056	0.113	1.057	0.060	0.113	1.062	0.061	0.113	1.062
Chronic pulmonary disease			0.101***	0.028	1.107***	0.102***	0.028	1.107***	0.102***	0.028	1.108***
Coagulopathy			-0.015	0.070	0.985	-0.005	0.070	0.995	-0.005	0.070	0.995
Depression			0.013	0.047	1.013	0.014	0.047	1.014	0.014	0.047	1.014
Diabetes, uncomplicated			0.047	0.031	1.049	0.047	0.031	1.048	0.047	0.031	1.048
Diabetes w/ chronic complications			0.156**	0.048	1.168**	0.153**	0.048	1.166**	0.153**	0.048	1.166**
Drug abuse			0.245	0.238	1.278	0.203	0.238	1.225	0.202	0.238	1.224
Hypertension			-0.022	0.029	0.979	-0.012	0.029	0.988	-0.012	0.029	0.988
Hypothyroidism			0.018	0.035	1.019	0.023	0.035	1.023	0.022	0.035	1.022
Liver disease			0.177	0.102	1.194	0.181	0.102	1.199	0.182	0.102	1.200
Lymphoma			-0.045	0.237	0.956	-0.026	0.237	0.975	-0.026	0.237	0.975
Fluid and electrolyte disorders			0.089**	0.031	1.093**	0.094**	0.031	1.098**	0.094**	0.031	1.098**
Metastatic cancer			-0.394	0.339	0.674	-0.386	0.339	0.680	-0.386	0.339	0.680
Other neurological disorders			0.007	0.049	1.007	0.010	0.049	1.010	0.010	0.049	1.011
Obesity			-0.049	0.047	0.952	-0.038	0.047	0.963	-0.038	0.047	0.963
Paralysis			-0.109	0.097	0.897	-0.116	0.097	0.890	-0.116	0.097	0.890
Peripheral vascular disorders			0.137***	0.038	1.147***	0.152***	0.038	1.165***	0.152***	0.038	1.164***
Psychoses			0.205*	0.086	1.228*	0.196*	0.086	1.216*	0.195*	0.086	1.215*
Pulmonary circulation disorders			0.081	0.323	1.085	0.081	0.323	1.085	0.080	0.323	1.083
Renal failure			0.209***	0.030	1.233***	0.216***	0.030	1.241***	0.216***	0.030	1.241***
Solid tumor without metastasis			-0.032	0.100	0.968	-0.031	0.100	0.970	-0.032	0.100	0.969
Peptic ulcer disease			0.140	0.641	1.150	0.142	0.641	1.153	0.142	0.641	1.153
Valvular disease			-0.303	0.246	0.738	-0.292	0.246	0.747	-0.290	0.246	0.748
Weight loss			0.057	0.085	1.059	0.061	0.085	1.063	0.062	0.085	1.064

Level 2: Hospital Characteristics											
California (Ref: Florida)						-0.029	0.039	0.972	-0.028	0.039	0.972
Ownership (Ref: Public)											
Private, not-for-profit						-0.078	0.049	0.925	-0.080	0.048	0.923
Private, for-profit						-0.064	0.056	0.938	-0.067	0.056	0.935
System affiliation						0.023	0.039	1.023	0.021	0.039	1.022
Cardiac catherization facility						-0.169***	0.050	0.845***	-0.163**	0.050	0.850**
Magnet hospital						-0.138*	0.067	0.871*	-0.147*	0.067	0.863*
Teaching intensity (Ref: non-teaching)											
Low						0.034	0.049	1.035	0.037	0.049	1.037
Medium						0.035	0.054	1.036	0.031	0.054	1.031
High						0.078	0.078	1.082	0.084	0.078	1.088
Hospital location (Ref: Rural)											
Micro/Division						-0.085	0.082	0.918	-0.083	0.082	0.920
Metro						-0.163*	0.077	0.850*	-0.159*	0.077	0.853*
Disproportionate Share Hospital (DSH) Index						0.162	0.127	1.176	0.151	0.127	1.163
Mean number of Elixhauser comorbid conditions						-0.071	0.041	0.931	-0.068	0.041	0.934
Proportion of patients with prior hospitalization for both HF and other conditions						-0.080	0.343	0.923	-0.083	0.342	0.920
Volume (Ref=1st quartile: smallest)						-0.000	0.000	1.000	-0.000	0.000	1.000
PQM (%): Discharge Composite Score						-0.000	0.002	1.000	-0.003	0.002	0.997
Interaction (Volume × PQM)									0.000	0.000	1.000
Random effects											
Hospital (intercept)											
Variance between hospitals	0.030***	0.007	0.028***	0.007		0.016***	0.006		0.015***	0.006	
ICC	0.009		0.008			0.005			0.005		

MOR	1.179		1.173			1.129			1.125		
n: level-1 (patients)	42051		42051			42051			42051		
n: level-2 (hospitals)	427		427			427			427		
AIC	37119		36381			36356			36356		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3 = 3.29$.
MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$
PQM: Process Quality Measure
Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 2:
Association of HF-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (ACE Inhibitor or ARB for LVSD)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.005*	0.002	1.005*	0.005*	0.002	1.005*	0.005*	0.002	1.005*
Female			-0.021	0.029	0.979	-0.026	0.029	0.975	-0.026	0.029	0.975
Race (Ref: White)											
Black			0.068	0.052	1.071	0.051	0.053	1.052	0.050	0.053	1.052
Hispanic			0.123**	0.045	1.131**	0.082	0.047	1.086	0.083	0.047	1.087
Others			-0.041	0.061	0.960	-0.090	0.062	0.914	-0.090	0.062	0.914
Disposition (Ref=Routine)											
Home Health Care			0.153***	0.036	1.165***	0.162***	0.036	1.175***	0.161***	0.036	1.175***
Nursing Home			0.451***	0.034	1.571***	0.454***	0.034	1.575***	0.454***	0.034	1.574***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.072	0.038	0.931	-0.053	0.038	0.948	-0.052	0.038	0.950
3rd quartile			0.004	0.039	1.004	0.029	0.040	1.029	0.031	0.040	1.031
4th quartile			-0.025	0.043	0.976	-0.001	0.044	0.999	0.003	0.044	1.003
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than heart failure			0.233*	0.095	1.262*	0.233*	0.095	1.263*	0.234*	0.095	1.263*
Prior admission (1y) for heart failure			0.303***	0.032	1.354***	0.304***	0.032	1.355***	0.304***	0.032	1.355***
Prior admission (1y) for both heart failure and other conditions			0.605***	0.037	1.831***	0.605***	0.038	1.830***	0.604***	0.038	1.830***
Comorbidities											

AIDS			1.568*	0.771	4.795*	1.574*	0.770	4.828*	1.578*	0.769	4.844*
Alcohol abuse			-0.007	0.119	0.993	-0.019	0.119	0.981	-0.019	0.119	0.981
Deficiency anemias			0.081**	0.030	1.084**	0.081**	0.030	1.084**	0.080**	0.030	1.084**
Rheumatoid arthritis			0.092	0.085	1.096	0.101	0.085	1.106	0.101	0.085	1.106
Chronic blood loss anemia			0.057	0.113	1.058	0.060	0.113	1.062	0.060	0.113	1.062
Chronic pulmonary disease			0.101***	0.028	1.106***	0.100***	0.028	1.105***	0.100***	0.028	1.106***
Coagulopathy			-0.011	0.070	0.989	-0.001	0.070	0.999	-0.001	0.070	0.999
Depression			0.016	0.048	1.016	0.017	0.048	1.017	0.017	0.048	1.017
Diabetes, uncomplicated			0.053	0.031	1.054	0.052	0.031	1.053	0.052	0.031	1.053
Diabetes w/ chronic complications			0.160***	0.048	1.174***	0.157**	0.048	1.170**	0.158**	0.048	1.171**
Drug abuse			0.273	0.238	1.314	0.235	0.238	1.265	0.235	0.238	1.265
Hypertension			-0.023	0.029	0.978	-0.013	0.029	0.987	-0.013	0.029	0.987
Hypothyroidism			0.016	0.035	1.016	0.020	0.035	1.021	0.020	0.035	1.020
Liver disease			0.165	0.104	1.179	0.169	0.104	1.184	0.169	0.104	1.184
Lymphoma			-0.031	0.237	0.970	-0.013	0.237	0.987	-0.015	0.237	0.985
Fluid and electrolyte disorders			0.088**	0.031	1.092**	0.093**	0.031	1.097**	0.093**	0.031	1.098**
Metastatic cancer			-0.393	0.339	0.675	-0.386	0.339	0.680	-0.387	0.339	0.679
Other neurological disorders			0.011	0.049	1.011	0.013	0.049	1.013	0.013	0.049	1.013
Obesity			-0.059	0.048	0.943	-0.049	0.048	0.952	-0.050	0.048	0.951
Paralysis			-0.115	0.098	0.891	-0.122	0.098	0.885	-0.121	0.098	0.886
Peripheral vascular disorders			0.144***	0.038	1.155***	0.159***	0.038	1.172***	0.158***	0.038	1.172***
Psychoses			0.213*	0.086	1.237*	0.201*	0.086	1.223*	0.201*	0.086	1.223*
Pulmonary circulation disorders			0.074	0.323	1.076	0.074	0.323	1.077	0.074	0.324	1.076
Renal failure			0.208***	0.031	1.231***	0.214***	0.031	1.239***	0.214***	0.031	1.239***
Solid tumor without metastasis			-0.056	0.101	0.945	-0.055	0.101	0.946	-0.055	0.101	0.947
Peptic ulcer disease			0.140	0.641	1.150	0.145	0.641	1.156	0.142	0.641	1.153
Valvular disease			-0.282	0.247	0.755	-0.272	0.247	0.762	-0.271	0.247	0.763
Weight loss			0.059	0.085	1.061	0.064	0.085	1.066	0.064	0.085	1.066
Level 2: Hospital Characteristics											

California (Ref: Florida)						-0.026	0.039	0.974	-0.021	0.039	0.979
Ownership (Ref: Public)											
Private, not-for-profit						-0.072	0.049	0.931	-0.077	0.049	0.926
Private, for-profit						-0.043	0.057	0.958	-0.049	0.057	0.952
System affiliation						0.015	0.040	1.015	0.014	0.040	1.015
Cardiac catherization facility						-0.164**	0.051	0.849**	-0.160**	0.051	0.852**
Magnet hospital						-0.126	0.067	0.881	-0.143*	0.070	0.867*
Teaching intensity (Ref: non-teaching)											
Low						0.032	0.049	1.033	0.036	0.049	1.036
Medium						0.036	0.053	1.037	0.037	0.053	1.037
High						0.049	0.082	1.050	0.049	0.082	1.050
Hospital location (Ref: Rural)											
Micro/Division						-0.108	0.083	0.898	-0.106	0.083	0.899
Metro						-0.189*	0.078	0.828*	-0.188*	0.078	0.829*
Disproportionate Share Hospital (DSH) Index						0.185	0.128	1.203	0.182	0.128	1.200
Mean number of Elixhauser comorbid conditions						-0.076	0.042	0.927	-0.079	0.042	0.924
Proportion of patients with prior hospitalization for both HF and other conditions						-0.088	0.350	0.916	-0.096	0.350	0.908
Volume (Ref=1st quartile: smallest)						-0.000	0.000	1.000	-0.000	0.000	1.000
PQM (%): ACE Inhibitor or ARB for LVSD						0.001	0.002	1.001	-0.001	0.003	0.999
Interaction (Volume × PQM)									0.000	0.000	1.000
Random effects											
Hospital (intercept)											
Variance between hospitals	0.029**		0.027**			0.015**			0.015**		
ICC	0.009		0.008			0.005			0.005		
MOR	1.177		1.170			1.125			1.123		

n: level-1 (patients)	41323		41323			41323			41323		
n: level-2 (hospitals)	396		396			396			396		
AIC	36406		35680			35657			35658		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3 = 3.29$.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 3:
Association of HF-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (Evaluation of LVS Function)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.005**	0.002	1.006**	0.006**	0.002	1.006**	0.006**	0.002	1.006**
Female			-0.020	0.028	0.981	-0.025	0.028	0.975	-0.025	0.028	0.975
Race (Ref: White)											
Black			0.082	0.052	1.086	0.064	0.052	1.066	0.066	0.052	1.068
Hispanic			0.132**	0.045	1.142**	0.094*	0.046	1.098*	0.094*	0.046	1.099*
Others			-0.038	0.060	0.963	-0.088	0.062	0.916	-0.088	0.062	0.916
Disposition (Ref=Routine)											
Home Health Care			0.149***	0.036	1.161***	0.160***	0.036	1.174***	0.160***	0.036	1.174***
Nursing Home			0.448***	0.034	1.566***	0.452***	0.034	1.572***	0.452***	0.034	1.571***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.068	0.038	0.934	-0.049	0.038	0.952	-0.049	0.038	0.952
3rd quartile			0.007	0.039	1.007	0.032	0.039	1.032	0.032	0.039	1.032
4th quartile			-0.014	0.042	0.986	0.007	0.044	1.007	0.011	0.044	1.011
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than heart failure			0.211*	0.095	1.235*	0.213*	0.095	1.237*	0.213*	0.095	1.237*
Prior admission (1y) for heart failure			0.304***	0.031	1.355***	0.304***	0.031	1.356***	0.304***	0.031	1.356***
Prior admission (1y) for both heart failure and other conditions			0.605***	0.037	1.832***	0.605***	0.037	1.831***	0.605***	0.037	1.831***
Comorbidities											

AIDS			1.562*	0.772	4.770*	1.584*	0.770	4.873*	1.588*	0.770	4.892*
Alcohol abuse			-0.005	0.119	0.995	-0.016	0.119	0.984	-0.015	0.119	0.985
Deficiency anemias			0.076*	0.030	1.079*	0.076*	0.030	1.079*	0.076*	0.030	1.079*
Rheumatoid arthritis			0.090	0.084	1.094	0.099	0.084	1.104	0.099	0.084	1.104
Chronic blood loss anemia			0.058	0.113	1.060	0.063	0.113	1.065	0.064	0.113	1.066
Chronic pulmonary disease			0.101***	0.028	1.106***	0.101***	0.028	1.106***	0.102***	0.028	1.107***
Coagulopathy			-0.015	0.070	0.986	-0.005	0.070	0.995	-0.004	0.070	0.996
Depression			0.014	0.047	1.014	0.015	0.047	1.015	0.015	0.047	1.015
Diabetes, uncomplicated			0.048	0.031	1.049	0.047	0.031	1.048	0.047	0.031	1.048
Diabetes w/ chronic complications			0.156**	0.048	1.169**	0.154**	0.048	1.166**	0.154**	0.048	1.167**
Drug abuse			0.246	0.238	1.278	0.203	0.238	1.225	0.201	0.238	1.223
Hypertension			-0.022	0.029	0.978	-0.013	0.029	0.987	-0.013	0.029	0.987
Hypothyroidism			0.018	0.035	1.018	0.022	0.035	1.022	0.021	0.035	1.022
Liver disease			0.178	0.102	1.194	0.181	0.102	1.199	0.182	0.102	1.200
Lymphoma			-0.044	0.237	0.957	-0.025	0.237	0.975	-0.025	0.237	0.976
Fluid and electrolyte disorders			0.089**	0.031	1.093**	0.094**	0.031	1.098**	0.094**	0.031	1.098**
Metastatic cancer			-0.394	0.339	0.675	-0.385	0.339	0.680	-0.385	0.339	0.680
Other neurological disorders			0.008	0.049	1.008	0.011	0.049	1.011	0.011	0.049	1.011
Obesity			-0.048	0.047	0.953	-0.038	0.047	0.963	-0.038	0.047	0.963
Paralysis			-0.108	0.097	0.897	-0.116	0.097	0.891	-0.116	0.097	0.890
Peripheral vascular disorders			0.138***	0.038	1.147***	0.152***	0.038	1.165***	0.152***	0.038	1.164***
Psychoses			0.206*	0.086	1.229*	0.196*	0.086	1.217*	0.195*	0.086	1.215*
Pulmonary circulation disorders			0.082	0.323	1.085	0.082	0.323	1.085	0.080	0.323	1.083
Renal failure			0.210***	0.030	1.234***	0.216***	0.030	1.241***	0.216***	0.030	1.241***
Solid tumor without metastasis			-0.032	0.100	0.969	-0.030	0.100	0.970	-0.031	0.100	0.970
Peptic ulcer disease			0.140	0.641	1.150	0.143	0.641	1.153	0.145	0.641	1.156
Valvular disease			-0.303	0.246	0.738	-0.292	0.246	0.747	-0.290	0.246	0.748
Weight loss			0.058	0.085	1.060	0.061	0.085	1.063	0.063	0.085	1.065
Level 2: Hospital Characteristics											

California (Ref: Florida)						-0.029	0.039	0.972	-0.030	0.039	0.970
Ownership (Ref: Public)											
Private, not-for-profit						-0.075	0.049	0.928	-0.073	0.048	0.930
Private, for-profit						-0.060	0.056	0.942	-0.061	0.056	0.941
System affiliation						0.025	0.039	1.026	0.021	0.039	1.022
Cardiac catherization facility						-0.166***	0.050	0.847***	-0.162**	0.050	0.851**
Magnet hospital						-0.138*	0.067	0.871*	-0.142*	0.067	0.868*
Teaching intensity (Ref: non-teaching)											
Low						0.035	0.049	1.035	0.037	0.049	1.038
Medium						0.035	0.054	1.036	0.030	0.054	1.031
High						0.077	0.078	1.080	0.078	0.078	1.082
Hospital location (Ref: Rural)											
Micro/Division						-0.086	0.082	0.917	-0.087	0.082	0.917
Metro						-0.165*	0.077	0.848*	-0.165*	0.077	0.848*
Disproportionate Share Hospital (DSH) Index						0.166	0.127	1.181	0.151	0.127	1.163
Mean number of Elixhauser comorbid conditions						-0.068	0.041	0.934	-0.068	0.041	0.934
Proportion of patients with prior hospitalization for both HF and other conditions						-0.096	0.343	0.908	-0.086	0.343	0.918
Volume (Ref=1st quartile: smallest)						-0.000	0.000	1.000	-0.000	0.000	1.000
PQM (%): Evaluation of LVS Function						-0.000	0.001	1.000	-0.002	0.001	0.998
Interaction (Volume × PQM)									0.000	0.000	1.000
Random effects											
Hospital (intercept)											
Variance between hospitals	0.030***		0.028***			0.016**			0.015***		
ICC	0.009		0.008			0.005			0.005		
MOR	1.179		1.173			1.129			1.124		

n: level-1 (patients)	42038		42038			42038			42038		
n: level-2 (hospitals)	425		425			425			425		
AIC	37098		36361			36337			36337		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3$ =3.29.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 4:
Association of HF-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (Discharge Instructions)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.006**	0.002	1.006**	0.006**	0.002	1.006**	0.006**	0.002	1.006**
Female			-0.019	0.028	0.981	-0.025	0.028	0.975	-0.025	0.028	0.975
Race (Ref: White)											
Black			0.082	0.052	1.085	0.064	0.052	1.066	0.064	0.052	1.066
Hispanic			0.131**	0.045	1.140**	0.091*	0.046	1.096*	0.091*	0.046	1.096*
Others			-0.038	0.060	0.962	-0.087	0.062	0.916	-0.087	0.062	0.917
Disposition (Ref=Routine)											
Home Health Care			0.149***	0.036	1.161***	0.160***	0.036	1.174***	0.160***	0.036	1.174***
Nursing Home			0.450***	0.034	1.569***	0.454***	0.034	1.575***	0.454***	0.034	1.575***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.066	0.038	0.936	-0.049	0.038	0.952	-0.049	0.038	0.952
3rd quartile			0.006	0.039	1.006	0.030	0.039	1.031	0.030	0.039	1.031
4th quartile			-0.015	0.042	0.985	0.006	0.044	1.006	0.006	0.044	1.006
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than heart failure			0.211*	0.095	1.235*	0.212*	0.095	1.236*	0.212*	0.095	1.236*
Prior admission (1y) for heart failure			0.304***	0.031	1.355***	0.305***	0.031	1.356***	0.305***	0.031	1.356***
Prior admission (1y) for both heart failure and other conditions			0.605***	0.037	1.832***	0.605***	0.037	1.831***	0.605***	0.037	1.831***
Comorbidities											

AIDS			1.562*	0.772	4.767*	1.577*	0.770	4.842*	1.577*	0.770	4.841*
Alcohol abuse			-0.006	0.119	0.994	-0.016	0.119	0.984	-0.016	0.119	0.984
Deficiency anemias			0.075*	0.030	1.078*	0.076*	0.030	1.079*	0.076*	0.030	1.079*
Rheumatoid arthritis			0.090	0.084	1.094	0.099	0.084	1.104	0.099	0.084	1.104
Chronic blood loss anemia			0.056	0.113	1.057	0.059	0.113	1.061	0.059	0.113	1.061
Chronic pulmonary disease			0.101***	0.028	1.107***	0.102***	0.028	1.107***	0.102***	0.028	1.107***
Coagulopathy			-0.015	0.070	0.985	-0.005	0.070	0.995	-0.005	0.070	0.995
Depression			0.013	0.047	1.013	0.014	0.047	1.014	0.014	0.047	1.014
Diabetes, uncomplicated			0.047	0.031	1.049	0.047	0.031	1.048	0.046	0.031	1.048
Diabetes w/ chronic complications			0.156**	0.048	1.168**	0.153**	0.048	1.166**	0.153**	0.048	1.165**
Drug abuse			0.246	0.238	1.278	0.203	0.238	1.224	0.202	0.238	1.224
Hypertension			-0.021	0.029	0.979	-0.012	0.029	0.988	-0.011	0.029	0.989
Hypothyroidism			0.019	0.035	1.019	0.023	0.035	1.023	0.022	0.035	1.023
Liver disease			0.178	0.102	1.194	0.182	0.102	1.199	0.182	0.102	1.199
Lymphoma			-0.045	0.237	0.956	-0.026	0.237	0.975	-0.026	0.237	0.974
Fluid and electrolyte disorders			0.088**	0.031	1.092**	0.093**	0.031	1.098**	0.093**	0.031	1.098**
Metastatic cancer			-0.394	0.339	0.674	-0.386	0.339	0.680	-0.387	0.339	0.679
Other neurological disorders			0.007	0.049	1.007	0.010	0.049	1.010	0.010	0.049	1.010
Obesity			-0.049	0.047	0.952	-0.038	0.047	0.963	-0.038	0.047	0.963
Paralysis			-0.108	0.097	0.898	-0.114	0.097	0.892	-0.114	0.097	0.892
Peripheral vascular disorders			0.137***	0.038	1.147***	0.152***	0.038	1.164***	0.152***	0.038	1.164***
Psychoses			0.205*	0.086	1.228*	0.195*	0.086	1.216*	0.195*	0.086	1.216*
Pulmonary circulation disorders			0.082	0.323	1.085	0.081	0.323	1.085	0.081	0.323	1.084
Renal failure			0.210***	0.030	1.233***	0.216***	0.030	1.241***	0.216***	0.030	1.241***
Solid tumor without metastasis			-0.032	0.100	0.968	-0.031	0.100	0.969	-0.032	0.100	0.969
Peptic ulcer disease			0.140	0.641	1.151	0.142	0.641	1.152	0.141	0.641	1.151
Valvular disease			-0.303	0.246	0.739	-0.292	0.246	0.747	-0.291	0.246	0.747
Weight loss			0.057	0.085	1.059	0.061	0.085	1.063	0.061	0.085	1.063
Level 2: Hospital Characteristics											

California (Ref: Florida)						-0.029	0.039	0.972	-0.029	0.039	0.972
Ownership (Ref: Public)											
Private, not-for-profit						-0.077	0.049	0.926	-0.080	0.049	0.923
Private, for-profit						-0.062	0.056	0.940	-0.064	0.057	0.938
System affiliation						0.019	0.039	1.020	0.020	0.039	1.020
Cardiac catherization facility						-0.173***	0.051	0.841***	-0.171***	0.051	0.842***
Magnet hospital						-0.139*	0.067	0.870*	-0.142*	0.068	0.868*
Teaching intensity (Ref: non-teaching)											
Low						0.033	0.049	1.034	0.033	0.049	1.033
Medium						0.033	0.054	1.033	0.032	0.054	1.032
High						0.079	0.078	1.082	0.081	0.078	1.084
Hospital location (Ref: Rural)											
Micro/Division						-0.093	0.083	0.911	-0.093	0.083	0.912
Metro						-0.167*	0.078	0.846*	-0.166*	0.078	0.847*
Disproportionate Share Hospital (DSH) Index						0.173	0.127	1.189	0.173	0.127	1.189
Mean number of Elixhauser comorbid conditions						-0.073	0.041	0.930	-0.071	0.041	0.931
Proportion of patients with prior hospitalization for both HF and other conditions						-0.067	0.343	0.935	-0.074	0.344	0.929
Volume (Ref=1st quartile: smallest)						-0.000	0.000	1.000	-0.000	0.000	1.000
PQM (%): Discharge Instructions						0.001	0.002	1.001	0.000	0.003	1.000
Interaction (Volume × PQM)									0.000	0.000	1.000
Random effects											
Hospital (intercept)											
Variance between hospitals	0.030***		0.028**			0.016***			0.015***		
ICC	0.009		0.008			0.005			0.005		
MOR	1.179		1.173			1.128			1.123		

n: level-1 (patients)	42044		42044			42044			42044		
n: level-2 (hospitals)	426		426			426			426		
AIC	37113		36375			36350			36352		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3$ =3.29.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 5:
Association of AMI-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (Admission Composite Measure)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.003	0.003	1.003	0.004	0.003	1.004	0.004	0.003	1.004
Female			-0.000	0.041	1.000	0.001	0.041	1.001	0.001	0.041	1.001
Race (Ref: White)											
Black			0.085	0.087	1.088	0.069	0.088	1.071	0.069	0.088	1.071
Hispanic			0.027	0.068	1.027	0.012	0.071	1.012	0.012	0.071	1.012
Others			-0.041	0.084	0.960	-0.063	0.086	0.939	-0.063	0.086	0.939
Disposition (Ref=Routine)											
Home Health Care			0.262***	0.055	1.300***	0.265***	0.055	1.304***	0.265***	0.055	1.304***
Nursing Home			0.632***	0.051	1.882***	0.632***	0.052	1.882***	0.632***	0.052	1.881***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.064	0.053	0.938	-0.043	0.053	0.957	-0.043	0.053	0.958
3rd quartile			-0.045	0.055	0.956	-0.018	0.056	0.982	-0.020	0.056	0.981
4th quartile			-0.083	0.058	0.921	-0.052	0.060	0.949	-0.053	0.060	0.949
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than AMI			0.076	0.261	1.079	0.072	0.261	1.075	0.072	0.261	1.075
Prior admission (1y) for AMI			0.301***	0.041	1.351***	0.302***	0.041	1.352***	0.302***	0.041	1.352***
Prior admission (1y) for both AMI and other conditions			0.397***	0.096	1.487***	0.389***	0.097	1.475***	0.389***	0.097	1.475***
AMI location: Anterior			0.048	0.068	1.049	0.048	0.068	1.049	0.047	0.068	1.049

AMI location: Other			0.051	0.062	1.052	0.055	0.062	1.056	0.055	0.062	1.056
Procedure											
CABG			-0.272***	0.077	0.762***	-0.261***	0.078	0.770***	-0.261***	0.078	0.770***
PTCA			0.101*	0.048	1.107*	0.113*	0.049	1.120*	0.114*	0.049	1.121*
Comorbidities											
AIDS			1.352	0.746	3.864	1.355	0.744	3.877	1.359	0.744	3.892
Alcohol abuse			0.088	0.154	1.092	0.088	0.154	1.092	0.087	0.154	1.091
Deficiency anemias			0.034	0.045	1.034	0.035	0.045	1.036	0.035	0.045	1.036
Rheumatoid arthritis			-0.044	0.116	0.957	-0.038	0.116	0.963	-0.037	0.116	0.963
Chronic blood loss anemia			-0.218	0.136	0.804	-0.213	0.136	0.808	-0.212	0.136	0.809
Congest Heart Failure			-0.202	0.253	0.817	-0.207	0.253	0.813	-0.208	0.253	0.812
Chronic pulmonary disease			0.168***	0.043	1.183***	0.171***	0.043	1.186***	0.171***	0.043	1.186***
Coagulopathy			-0.155	0.093	0.856	-0.150	0.094	0.861	-0.150	0.094	0.861
Depression			-0.010	0.073	0.990	-0.006	0.073	0.994	-0.006	0.073	0.994
Diabetes, uncomplicated			0.144**	0.044	1.155**	0.143**	0.044	1.154**	0.143**	0.044	1.154**
Diabetes w/ chronic complications			0.232**	0.077	1.261**	0.235**	0.077	1.265**	0.235**	0.077	1.264**
Drug abuse			-0.255	0.368	0.775	-0.248	0.369	0.780	-0.249	0.369	0.779
Hypertension			0.047	0.044	1.048	0.046	0.044	1.047	0.046	0.044	1.047
Hypothyroidism			0.044	0.055	1.046	0.045	0.055	1.046	0.045	0.055	1.046
Liver disease			0.020	0.191	1.020	0.018	0.191	1.018	0.019	0.191	1.019
Lymphoma			0.210	0.409	1.233	0.222	0.410	1.248	0.222	0.409	1.248
Fluid and electrolyte disorders			0.053	0.046	1.054	0.056	0.046	1.057	0.055	0.046	1.057
Metastatic cancer			-1.268*	0.598	0.281*	-1.281*	0.598	0.278*	-1.281*	0.598	0.278*
Other neurological disorders			-0.125	0.067	0.882	-0.124	0.067	0.883	-0.124	0.067	0.883
Obesity			-0.052	0.072	0.950	-0.046	0.072	0.955	-0.046	0.072	0.955
Paralysis			0.008	0.107	1.008	0.013	0.107	1.013	0.013	0.107	1.013
Peripheral vascular disorders			0.071	0.051	1.074	0.074	0.052	1.076	0.074	0.052	1.077
Psychoses			0.074	0.119	1.077	0.079	0.119	1.083	0.079	0.119	1.082
Pulmonary circulation disorders			0.320	0.839	1.377	0.310	0.839	1.364	0.313	0.839	1.367
Renal failure			0.189***	0.048	1.208***	0.189***	0.048	1.209***	0.189***	0.048	1.209***

Solid tumor without metastasis			-0.169	0.141	0.845	-0.165	0.141	0.848	-0.165	0.141	0.848
Peptic ulcer disease			1.274	0.691	3.575	1.281	0.691	3.599	1.281	0.691	3.600
Valvular disease			-0.298	0.410	0.742	-0.292	0.409	0.747	-0.293	0.409	0.746
Weight loss			-0.099	0.127	0.906	-0.094	0.127	0.910	-0.094	0.127	0.910
Level 2: Hospital Characteristics											
California (Ref: Florida)						0.065	0.057	1.067	0.067	0.057	1.069
Ownership (Ref: Public)											1.000
Private, not-for-profit						-0.019	0.068	0.981	-0.015	0.068	0.985
Private, for-profit						-0.090	0.082	0.914	-0.089	0.082	0.915
System affiliation						0.084	0.055	1.088	0.079	0.056	1.082
Cardiac catherization facility						-0.095	0.095	0.909	-0.095	0.095	0.909
Magnet hospital						-0.124	0.088	0.883	-0.130	0.088	0.878
Teaching intensity (Ref: non-teaching)											
Low						0.117	0.067	1.124	0.116	0.066	1.123
Medium						-0.060	0.075	0.942	-0.059	0.074	0.943
High						0.188	0.109	1.207	0.187	0.109	1.206
Hospital location (Ref: Rural)											
Micro/Division						-0.285*	0.130	0.752*	-0.286*	0.130	0.751*
Metro						-0.335**	0.123	0.716**	-0.333**	0.123	0.716**
Disproportionate Share Hospital (DSH) Index						0.223	0.192	1.250	0.214	0.193	1.239
Mean number of Elixhauser comorbid conditions						-0.062	0.056	0.940	-0.062	0.056	0.940
Proportion of patients with prior hospitalization for both AMI and other conditions						0.049	0.662	1.050	0.064	0.662	1.066
Hospital AMI Volume						-0.000	0.000	1.000	-0.000	0.000	1.000
PQM (%): Admission Composite Measure						-0.010	0.006	0.990	-0.013	0.008	0.987
									0.000	0.000	1.000
Interaction (Volume × PQM)											

Random effects											
Hospital (intercept)											
Variance between hospitals	0.040***		0.029***			0.020*			0.019*		
ICC	0.012		0.009			0.006			0.006		
MOR	1.209		1.175			1.144			1.142		
n: level-1 (patients)	21635		21635			21635			21635		
n: level-2 (hospitals)	380		380			380			380		
AIC	18623		18261			18268			18269		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3 = 3.29$.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 6:
Association of AMI-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (Discharge Composite Measure)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.003	0.003	1.003	0.003	0.003	1.003	0.003	0.003	1.003
Female			0.002	0.041	1.002	0.003	0.041	1.003	0.003	0.041	1.003
Race (Ref: White)											
Black			0.080	0.088	1.083	0.061	0.088	1.063	0.061	0.088	1.063
Hispanic			0.016	0.069	1.016	0.002	0.071	1.002	0.005	0.071	1.005
Others			-0.031	0.084	0.970	-0.051	0.087	0.950	-0.051	0.087	0.950
Disposition (Ref=Routine)											
Home Health Care			0.271***	0.055	1.311***	0.272***	0.056	1.313***	0.272***	0.056	1.312***
Nursing Home			0.629***	0.052	1.876***	0.626***	0.052	1.871***	0.626***	0.052	1.870***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.065	0.053	0.937	-0.047	0.054	0.954	-0.049	0.054	0.952
3rd quartile			-0.048	0.056	0.953	-0.028	0.057	0.973	-0.029	0.057	0.972
4th quartile			-0.088	0.059	0.915	-0.060	0.061	0.942	-0.059	0.061	0.942
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than AMI			0.083	0.261	1.087	0.074	0.261	1.077	0.076	0.261	1.079
Prior admission (1y) for AMI			0.304***	0.041	1.356***	0.305***	0.041	1.357***	0.306***	0.041	1.357***
Prior admission (1y) for both AMI and other conditions			0.409***	0.097	1.506***	0.405***	0.098	1.499***	0.405***	0.098	1.499***
AMI location: Anterior			0.052	0.069	1.053	0.054	0.069	1.056	0.054	0.069	1.056

AMI location: Other			0.046	0.062	1.047	0.051	0.062	1.052	0.051	0.062	1.052
Procedure											
CABG			-0.266***	0.077	0.766***	-0.253**	0.078	0.776**	-0.253**	0.078	0.776**
PTCA			0.103*	0.048	1.108*	0.116*	0.049	1.123*	0.117*	0.049	1.124*
Comorbidities											
AIDS			1.355	0.746	3.878	1.341	0.745	3.822	1.345	0.744	3.837
Alcohol abuse			0.059	0.156	1.061	0.059	0.156	1.061	0.059	0.156	1.061
Deficiency anemias			0.037	0.046	1.038	0.039	0.046	1.040	0.039	0.046	1.040
Rheumatoid arthritis			-0.032	0.116	0.968	-0.025	0.116	0.975	-0.024	0.116	0.977
Chronic blood loss anemia			-0.208	0.136	0.812	-0.206	0.136	0.814	-0.207	0.136	0.813
Congest Heart Failure			-0.284	0.263	0.753	-0.290	0.263	0.748	-0.292	0.263	0.747
Chronic pulmonary disease			0.168***	0.043	1.183***	0.170***	0.043	1.185***	0.170***	0.043	1.185***
Coagulopathy			-0.135	0.093	0.874	-0.131	0.094	0.877	-0.131	0.094	0.877
Depression			-0.013	0.074	0.987	-0.011	0.074	0.989	-0.011	0.074	0.989
Diabetes, uncomplicated			0.143**	0.044	1.154**	0.142**	0.044	1.153**	0.142**	0.044	1.153**
Diabetes w/ chronic complications			0.234**	0.077	1.264**	0.238**	0.077	1.268**	0.238**	0.077	1.268**
Drug abuse			-0.247	0.368	0.781	-0.247	0.368	0.781	-0.248	0.368	0.780
Hypertension			0.052	0.044	1.054	0.051	0.044	1.052	0.052	0.044	1.053
Hypothyroidism			0.044	0.055	1.045	0.045	0.055	1.046	0.044	0.055	1.045
Liver disease			0.015	0.194	1.015	0.014	0.193	1.014	0.014	0.193	1.014
Lymphoma			0.218	0.409	1.244	0.228	0.409	1.256	0.226	0.409	1.253
Fluid and electrolyte disorders			0.047	0.046	1.049	0.051	0.047	1.053	0.051	0.047	1.053
Metastatic cancer			-1.207*	0.599	0.299*	-1.229*	0.600	0.293*	-1.232*	0.600	0.292*
Other neurological disorders			-0.114	0.067	0.892	-0.114	0.067	0.893	-0.114	0.067	0.892
Obesity			-0.052	0.072	0.949	-0.048	0.072	0.953	-0.047	0.072	0.954
Paralysis			0.018	0.108	1.018	0.022	0.108	1.022	0.021	0.108	1.021
Peripheral vascular disorders			0.072	0.052	1.075	0.074	0.052	1.077	0.075	0.052	1.077
Psychoses			0.063	0.120	1.065	0.065	0.120	1.067	0.065	0.120	1.067
Pulmonary circulation disorders			0.306	0.841	1.359	0.299	0.841	1.349	0.299	0.840	1.349
Renal failure			0.181***	0.048	1.198***	0.181***	0.048	1.199***	0.181***	0.048	1.199***

Solid tumor without metastasis			-0.200	0.144	0.819	-0.196	0.144	0.822	-0.196	0.144	0.822
Peptic ulcer disease			1.526*	0.730	4.600*	1.555*	0.731	4.736*	1.562*	0.732	4.769*
Valvular disease			-0.215	0.412	0.807	-0.211	0.411	0.809	-0.208	0.411	0.812
Weight loss			-0.090	0.128	0.914	-0.083	0.128	0.920	-0.083	0.128	0.920
Level 2: Hospital Characteristics											
California (Ref: Florida)						0.088	0.058	1.092	0.093	0.058	1.098
Ownership (Ref: Public)											
Private, not-for-profit						-0.015	0.069	0.985	-0.014	0.068	0.986
Private, for-profit						-0.077	0.082	0.925	-0.074	0.082	0.929
System affiliation						0.069	0.056	1.071	0.062	0.056	1.064
Cardiac catherization facility						-0.073	0.106	0.930	-0.058	0.108	0.944
Magnet hospital						-0.123	0.088	0.884	-0.135	0.089	0.874
Teaching intensity (Ref: non-teaching)											
Low						0.116	0.067	1.122	0.120	0.067	1.128
Medium						-0.062	0.075	0.940	-0.054	0.076	0.947
High						0.197	0.110	1.218	0.201	0.109	1.223
Hospital location (Ref: Rural)											
Micro/Division						-0.262	0.138	0.770	-0.261	0.137	0.770
Metro						-0.291*	0.131	0.747*	-0.286*	0.131	0.751*
Disproportionate Share Hospital (DSH) Index						0.226	0.196	1.254	0.215	0.196	1.240
Mean number of Elixhauser comorbid conditions						-0.045	0.058	0.956	-0.045	0.057	0.956
Proportion of patients with prior hospitalization for both AMI and other conditions						-0.071	0.703	0.932	-0.007	0.704	0.993
Hospital AMI Volume						-0.000	0.000	1.000	-0.000	0.000	1.000
PQM (%): Discharge Composite Measure						-0.004	0.005	0.996	-0.007	0.006	0.993
									0.000	0.000	1.000
Interaction (Volume × PQM)											

Random effects											
Hospital (intercept)											
Variance between hospitals	0.040***		0.029***			0.021**			0.020*		
ICC	0.012		9			0.006			0.006		
MOR	1.209		1.177			1.148			1.145		
n: level-1 (patients)	21367		21367			21367			21367		
n: level-2 (hospitals)	346		346			346			346		
AIC	18360		18009			18020			18022		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3 = 3.29$.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 7:
Association of AMI-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (Global Composite Measure)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.003	0.003	1.003	0.004	0.003	1.004	0.004	0.003	1.004
Female			0.005	0.041	1.005	0.006	0.041	1.006	0.006	0.041	1.006
Race (Ref: White)											
Black			0.081	0.087	1.084	0.064	0.088	1.066	0.064	0.088	1.066
Hispanic			0.027	0.068	1.028	0.012	0.071	1.012	0.014	0.071	1.014
Others			-0.041	0.084	0.960	-0.064	0.086	0.938	-0.063	0.086	0.939
Disposition (Ref=Routine)											
Home Health Care			0.262***	0.055	1.300***	0.265***	0.055	1.303***	0.265***	0.055	1.303***
Nursing Home			0.628***	0.051	1.873***	0.626***	0.052	1.870***	0.625***	0.052	1.869***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.066	0.053	0.936	-0.044	0.053	0.957	-0.045	0.053	0.956
3rd quartile			-0.050	0.055	0.951	-0.024	0.056	0.976	-0.026	0.056	0.974
4th quartile			-0.086	0.058	0.918	-0.054	0.060	0.947	-0.053	0.060	0.948
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than AMI			0.075	0.261	1.078	0.067	0.261	1.070	0.067	0.261	1.070
Prior admission (1y) for AMI			0.302***	0.041	1.353***	0.304***	0.041	1.355***	0.304***	0.041	1.355***
Prior admission (1y) for both AMI and other conditions			0.399***	0.096	1.490***	0.393***	0.097	1.481***	0.393***	0.097	1.481***
AMI location: Anterior			0.052	0.068	1.053	0.051	0.068	1.053	0.052	0.068	1.053

AMI location: Other			0.056	0.062	1.057	0.059	0.062	1.061	0.059	0.062	1.061
Procedure											
CABG			-0.268***	0.077	0.765***	-0.252**	0.078	0.777**	-0.252**	0.078	0.777**
PTCA			0.096*	0.048	1.101*	0.113*	0.049	1.119*	0.115*	0.049	1.121*
Comorbidities											
AIDS			1.353	0.746	3.868	1.345	0.744	3.838	1.351	0.744	3.861
Alcohol abuse			0.090	0.154	1.094	0.090	0.154	1.094	0.089	0.154	1.093
Deficiency anemias			0.032	0.045	1.033	0.035	0.045	1.036	0.035	0.045	1.036
Rheumatoid arthritis			-0.054	0.116	0.948	-0.047	0.116	0.954	-0.045	0.116	0.956
Chronic blood loss anemia			-0.222	0.136	0.801	-0.217	0.136	0.805	-0.217	0.136	0.805
Congest Heart Failure			-0.193	0.254	0.824	-0.197	0.253	0.821	-0.199	0.253	0.819
Chronic pulmonary disease			0.170***	0.043	1.185***	0.172***	0.043	1.188***	0.172***	0.043	1.188***
Coagulopathy			-0.148	0.093	0.862	-0.142	0.093	0.868	-0.141	0.093	0.869
Depression			-0.019	0.073	0.982	-0.014	0.073	0.986	-0.014	0.073	0.986
Diabetes, uncomplicated			0.142**	0.044	1.153**	0.141**	0.044	1.152**	0.141**	0.044	1.152**
Diabetes w/ chronic complications			0.228**	0.077	1.257**	0.230**	0.077	1.259**	0.229**	0.077	1.258**
Drug abuse			-0.258	0.368	0.773	-0.255	0.368	0.775	-0.257	0.368	0.773
Hypertension			0.047	0.044	1.049	0.048	0.044	1.049	0.048	0.044	1.049
Hypothyroidism			0.041	0.055	1.041	0.042	0.055	1.042	0.041	0.055	1.042
Liver disease			0.025	0.191	1.026	0.025	0.191	1.026	0.025	0.191	1.026
Lymphoma			0.209	0.409	1.232	0.221	0.409	1.247	0.220	0.409	1.246
Fluid and electrolyte disorders			0.052	0.046	1.054	0.056	0.046	1.058	0.056	0.046	1.057
Metastatic cancer			-1.254*	0.598	0.285*	-1.268*	0.599	0.282*	-1.270*	0.599	0.281*
Other neurological disorders			-0.121	0.067	0.886	-0.119	0.067	0.888	-0.119	0.067	0.888
Obesity			-0.045	0.072	0.956	-0.039	0.072	0.961	-0.038	0.072	0.962
Paralysis			0.016	0.107	1.016	0.019	0.107	1.020	0.019	0.107	1.019
Peripheral vascular disorders			0.073	0.051	1.076	0.076	0.052	1.079	0.077	0.052	1.080
Psychoses			0.080	0.119	1.083	0.084	0.119	1.087	0.083	0.119	1.086
Pulmonary circulation disorders			0.317	0.839	1.373	0.313	0.838	1.367	0.315	0.838	1.370
Renal failure			0.190***	0.048	1.209***	0.191***	0.048	1.211***	0.191***	0.048	1.210***

Solid tumor without metastasis			-0.170	0.141	0.844	-0.165	0.141	0.847	-0.165	0.141	0.848
Peptic ulcer disease			1.525*	0.730	4.595*	1.548*	0.731	4.701*	1.550*	0.732	4.712*
Valvular disease			-0.308	0.410	0.735	-0.305	0.410	0.737	-0.305	0.410	0.737
Weight loss			-0.099	0.127	0.906	-0.094	0.127	0.910	-0.094	0.127	0.910
Level 2: Hospital Characteristics											
California (Ref: Florida)						0.073	0.057	1.076	0.080	0.057	1.083
Ownership (Ref: Public)											
Private, not-for-profit						-0.012	0.068	0.988	-0.007	0.068	0.994
Private, for-profit						-0.079	0.082	0.924	-0.075	0.082	0.928
System affiliation						0.075	0.056	1.078	0.064	0.057	1.066
Cardiac catherization facility						-0.106	0.096	0.899	-0.095	0.096	0.909
Magnet hospital						-0.128	0.088	0.880	-0.142	0.089	0.868
Teaching intensity (Ref: non-teaching)											
Low						0.117	0.067	1.124	0.117	0.066	1.125
Medium						-0.062	0.075	0.940	-0.055	0.075	0.947
High						0.203	0.109	1.226	0.206	0.108	1.229
Hospital location (Ref: Rural)											
Micro/Division						-0.293*	0.131	0.746*	-0.296*	0.130	0.744*
Metro						-0.331**	0.125	0.718**	-0.329**	0.124	0.720**
Disproportionate Share Hospital (DSH) Index						0.221	0.193	1.247	0.200	0.194	1.222
Mean number of Elixhauser comorbid conditions						-0.065	0.057	0.937	-0.065	0.056	0.938
Proportion of patients with prior hospitalization for both AMI and other conditions						-0.010	0.667	0.990	0.048	0.667	1.049
Hospital AMI Volume						-0.000	0.000	1.000	-0.000	0.000	1.000
PQM (%): Global Composite Measure						-0.008	0.006	0.992	-0.014	0.008	0.987
									0.000	0.000	1.000
Interaction (Volume × PQM)											

Random effects											
Hospital (intercept)											
Variance between hospitals	0.040***		0.029***			0.020**			0.019*		
ICC	0.012		0.009			0.006			0.006		
MOR	1.210		1.176			1.146			1.142		
n: level-1 (patients)	21580		21580			21580			21580		
n: level-2 (hospitals)	371		371			371			371		
AIC	18594		18234			18241			18242		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3 = 3.29$.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 8:
Association of AMI-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (ACE Inhibitor or ARB for LVSD)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.005	0.003	1.005	0.005	0.003	1.005	0.005	0.003	1.005
Female			-0.005	0.044	0.995	-0.004	0.044	0.996	-0.003	0.044	0.997
Race (Ref: White)											
Black			0.039	0.094	1.040	0.028	0.094	1.029	0.028	0.094	1.028
Hispanic			0.015	0.074	1.015	0.020	0.076	1.021	0.021	0.076	1.021
Others			-0.068	0.093	0.934	-0.079	0.095	0.925	-0.078	0.095	0.925
Disposition (Ref=Routine)											
Home Health Care			0.294***	0.059	1.342***	0.294***	0.059	1.342***	0.294***	0.059	1.341***
Nursing Home			0.626***	0.056	1.870***	0.625***	0.056	1.868***	0.624***	0.056	1.867***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.065	0.057	0.937	-0.051	0.057	0.951	-0.051	0.057	0.950
3rd quartile			-0.030	0.059	0.970	-0.018	0.060	0.982	-0.018	0.060	0.983
4th quartile			-0.068	0.064	0.934	-0.045	0.065	0.956	-0.044	0.065	0.957
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than AMI			0.178	0.271	1.195	0.169	0.271	1.185	0.169	0.271	1.184
Prior admission (1y) for AMI			0.317***	0.044	1.373***	0.320***	0.044	1.377***	0.320***	0.044	1.377***
Prior admission (1y) for both AMI and other conditions			0.385***	0.105	1.469***	0.387***	0.106	1.473***	0.388***	0.106	1.473***
AMI location: Anterior			0.051	0.072	1.052	0.051	0.072	1.052	0.051	0.072	1.053

AMI location: Other			0.034	0.065	1.035	0.037	0.065	1.038	0.037	0.065	1.038
Procedure											
CABG			-0.248**	0.079	0.781**	-0.246**	0.079	0.782**	-0.245**	0.079	0.782**
PTCA			0.125*	0.050	1.133*	0.127*	0.050	1.136*	0.128*	0.050	1.137*
Comorbidities											
AIDS			1.177	0.882	3.244	1.198	0.883	3.313	1.201	0.883	3.325
Alcohol abuse			-0.002	0.169	0.998	-0.008	0.169	0.992	-0.008	0.169	0.992
Deficiency anemias			0.051	0.049	1.053	0.054	0.049	1.055	0.054	0.049	1.056
Rheumatoid arthritis			-0.081	0.126	0.922	-0.078	0.126	0.925	-0.077	0.126	0.926
Chronic blood loss anemia			-0.038	0.140	0.963	-0.036	0.140	0.965	-0.036	0.140	0.965
Congest Heart Failure			-0.357	0.292	0.700	-0.360	0.292	0.698	-0.361	0.292	0.697
Chronic pulmonary disease			0.157***	0.046	1.170***	0.160***	0.046	1.174***	0.160***	0.046	1.174***
Coagulopathy			-0.158	0.100	0.854	-0.152	0.100	0.859	-0.151	0.100	0.859
Depression			-0.072	0.081	0.931	-0.069	0.081	0.933	-0.069	0.081	0.933
Diabetes, uncomplicated			0.148**	0.047	1.160**	0.148**	0.047	1.159**	0.148**	0.047	1.160**
Diabetes w/ chronic complications			0.202*	0.084	1.224*	0.206*	0.084	1.229*	0.206*	0.084	1.228*
Drug abuse			-0.109	0.373	0.897	-0.112	0.373	0.894	-0.113	0.373	0.894
Hypertension			0.075	0.047	1.078	0.072	0.047	1.075	0.072	0.047	1.075
Hypothyroidism			0.024	0.059	1.024	0.023	0.059	1.023	0.023	0.059	1.023
Liver disease			-0.088	0.223	0.916	-0.087	0.222	0.917	-0.087	0.222	0.917
Lymphoma			0.093	0.433	1.097	0.115	0.433	1.122	0.115	0.433	1.122
Fluid and electrolyte disorders			0.060	0.050	1.062	0.067	0.050	1.069	0.067	0.050	1.069
Metastatic cancer			-1.451*	0.729	0.234*	-1.465*	0.728	0.231*	-1.467*	0.728	0.231*
Other neurological disorders			-0.099	0.073	0.905	-0.096	0.073	0.909	-0.096	0.073	0.909
Obesity			-0.064	0.076	0.938	-0.059	0.076	0.942	-0.059	0.076	0.943
Paralysis			0.089	0.117	1.093	0.094	0.117	1.099	0.095	0.117	1.099
Peripheral vascular disorders			0.063	0.055	1.065	0.064	0.055	1.066	0.064	0.055	1.066
Psychoses			0.223	0.124	1.250	0.232	0.124	1.261	0.233	0.124	1.262
Pulmonary circulation disorders			0.477	0.856	1.612	0.497	0.855	1.644	0.498	0.855	1.645
Renal failure			0.181***	0.052	1.198***	0.179***	0.052	1.196***	0.179***	0.052	1.196***

Solid tumor without metastasis			-0.211	0.152	0.810	-0.209	0.151	0.811	-0.209	0.151	0.812
Peptic ulcer disease			1.263	0.786	3.537	1.308	0.787	3.699	1.311	0.787	3.712
Valvular disease			-0.185	0.439	0.831	-0.182	0.437	0.834	-0.181	0.438	0.834
Weight loss			-0.124	0.142	0.883	-0.117	0.142	0.890	-0.117	0.142	0.890
Level 2: Hospital Characteristics											
California (Ref: Florida)						0.099	0.065	1.104	0.099	0.065	1.105
Ownership (Ref: Public)											
Private, not-for-profit						-0.020	0.074	0.980	-0.018	0.074	0.982
Private, for-profit						-0.092	0.090	0.912	-0.089	0.091	0.915
System affiliation						0.091	0.062	1.095	0.091	0.062	1.095
Cardiac catherization facility						0.088	0.268	1.092	0.078	0.269	1.081
Magnet hospital						-0.186*	0.095	0.830*	-0.191*	0.096	0.826*
Teaching intensity (Ref: non-teaching)											
Low						0.102	0.071	1.107	0.104	0.072	1.110
Medium						-0.042	0.080	0.959	-0.038	0.080	0.963
High						0.232*	0.118	1.262*	0.235*	0.118	1.265*
Hospital location (Ref: Rural)											
Micro/Division						-0.388*	0.171	0.679*	-0.391*	0.171	0.677*
Metro						-0.422*	0.166	0.656*	-0.425*	0.166	0.654*
Disproportionate Share Hospital (DSH) Index						0.137	0.234	1.147	0.124	0.236	1.132
Mean number of Elixhauser comorbid conditions						-0.085	0.070	0.919	-0.089	0.071	0.915
Proportion of patients with prior hospitalization for both AMI and other conditions						-0.516	0.912	0.597	-0.506	0.911	0.603
Hospital AMI Volume						-0.000	0.000	1.000	-0.000	0.000	1.000
PQM (%): ACE Inhibitor or ARB for LVSD						-0.001	0.003	0.999	-0.003	0.006	0.997
									0.000	0.000	1.000
Interaction (Volume × PQM)											

Random effects											
Hospital (intercept)											
Variance between hospitals	0.040***		0.033***			0.023**			0.023**		
ICC	0.012		0.010			0.007			0.007		
MOR	1.211		1.190			1.156			1.156		
n: level-1 (patients)	19086		19086			19086			19086		
n: level-2 (hospitals)	222		222			222			222		
AIC	16251		15945			15956			15958		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3 = 3.29$.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 9:
Association of AMI-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (Aspirin at Arrival)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.003	0.003	1.003	0.004	0.003	1.004	0.004	0.003	1.004
Female			-0.000	0.041	1.000	0.000	0.041	1.000	0.000	0.041	1.000
Race (Ref: White)											
Black			0.084	0.087	1.088	0.070	0.088	1.072	0.070	0.088	1.072
Hispanic			0.027	0.068	1.027	0.014	0.071	1.014	0.017	0.071	1.017
Others			-0.041	0.084	0.960	-0.062	0.086	0.940	-0.060	0.086	0.942
Disposition (Ref=Routine)											
Home Health Care			0.263***	0.055	1.301***	0.266***	0.055	1.304***	0.266***	0.055	1.305***
Nursing Home			0.632***	0.051	1.882***	0.631***	0.052	1.879***	0.631***	0.052	1.880***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.063	0.053	0.939	-0.041	0.053	0.960	-0.041	0.053	0.960
3rd quartile			-0.045	0.055	0.956	-0.019	0.056	0.981	-0.020	0.056	0.980
4th quartile			-0.083	0.058	0.921	-0.050	0.060	0.951	-0.049	0.060	0.952
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than AMI			0.075	0.261	1.078	0.067	0.261	1.069	0.067	0.261	1.070
Prior admission (1y) for AMI			0.301***	0.041	1.351***	0.302***	0.041	1.352***	0.302***	0.041	1.352***
Prior admission (1y) for both AMI and other conditions			0.396***	0.096	1.486***	0.389***	0.097	1.476***	0.389***	0.097	1.476***
AMI location: Anterior			0.048	0.068	1.049	0.047	0.068	1.048	0.047	0.068	1.049

AMI location: Other			0.052	0.062	1.053	0.056	0.062	1.057	0.056	0.062	1.057
Procedure											
CABG			-0.273***	0.077	0.761***	-0.258***	0.078	0.773***	-0.258***	0.078	0.773***
PTCA			0.101*	0.048	1.106*	0.117*	0.049	1.124*	0.119*	0.049	1.126*
Comorbidities											
AIDS			1.352	0.746	3.864	1.334	0.744	3.797	1.340	0.744	3.818
Alcohol abuse			0.088	0.154	1.092	0.087	0.154	1.091	0.087	0.154	1.091
Deficiency anemias			0.034	0.045	1.035	0.037	0.045	1.038	0.037	0.045	1.038
Rheumatoid arthritis			-0.044	0.116	0.957	-0.038	0.116	0.963	-0.037	0.116	0.964
Chronic blood loss anemia			-0.218	0.136	0.804	-0.213	0.136	0.808	-0.213	0.136	0.808
Congest Heart Failure			-0.190	0.254	0.827	-0.192	0.253	0.825	-0.193	0.253	0.824
Chronic pulmonary disease			0.168***	0.043	1.183***	0.170***	0.043	1.185***	0.171***	0.043	1.186***
Coagulopathy			-0.156	0.093	0.856	-0.151	0.094	0.860	-0.150	0.094	0.861
Depression			-0.010	0.073	0.990	-0.007	0.073	0.993	-0.008	0.073	0.992
Diabetes, uncomplicated			0.144**	0.044	1.155**	0.144**	0.044	1.155**	0.144**	0.044	1.155**
Diabetes w/ chronic complications			0.232**	0.077	1.261**	0.234**	0.077	1.264**	0.234**	0.077	1.264**
Drug abuse			-0.255	0.368	0.775	-0.254	0.368	0.776	-0.257	0.368	0.773
Hypertension			0.046	0.044	1.047	0.047	0.044	1.048	0.047	0.044	1.048
Hypothyroidism			0.044	0.055	1.045	0.046	0.055	1.047	0.046	0.055	1.047
Liver disease			0.019	0.191	1.019	0.020	0.191	1.020	0.019	0.191	1.020
Lymphoma			0.209	0.409	1.233	0.221	0.409	1.247	0.222	0.409	1.249
Fluid and electrolyte disorders			0.053	0.046	1.055	0.057	0.046	1.058	0.056	0.046	1.058
Metastatic cancer			-1.269*	0.598	0.281*	-1.283*	0.598	0.277*	-1.284*	0.598	0.277*
Other neurological disorders			-0.125	0.067	0.882	-0.123	0.067	0.884	-0.123	0.067	0.884
Obesity			-0.052	0.072	0.949	-0.047	0.072	0.954	-0.045	0.072	0.956
Paralysis			0.007	0.107	1.007	0.012	0.107	1.012	0.011	0.107	1.011
Peripheral vascular disorders			0.071	0.051	1.073	0.073	0.052	1.076	0.074	0.052	1.077
Psychoses			0.073	0.119	1.076	0.078	0.119	1.081	0.078	0.119	1.081
Pulmonary circulation disorders			0.318	0.839	1.374	0.308	0.839	1.361	0.309	0.838	1.362
Renal failure			0.188***	0.048	1.207***	0.189***	0.048	1.208***	0.189***	0.048	1.209***

Solid tumor without metastasis			-0.170	0.141	0.844	-0.165	0.141	0.848	-0.166	0.141	0.847
Peptic ulcer disease			1.273	0.691	3.572	1.296	0.691	3.656	1.295	0.691	3.650
Valvular disease			-0.307	0.410	0.736	-0.302	0.409	0.739	-0.302	0.409	0.740
Weight loss			-0.100	0.127	0.905	-0.094	0.127	0.910	-0.095	0.127	0.909
Level 2: Hospital Characteristics											
California (Ref: Florida)						0.066	0.057	1.069	0.070	0.057	1.073
Ownership (Ref: Public)											
Private, not-for-profit						-0.007	0.068	0.993	-0.010	0.068	0.990
Private, for-profit						-0.067	0.081	0.936	-0.072	0.081	0.930
System affiliation						0.076	0.055	1.079	0.075	0.055	1.078
Cardiac catherization facility						-0.087	0.095	0.916	-0.080	0.095	0.923
Magnet hospital						-0.123	0.088	0.884	-0.133	0.088	0.876
Teaching intensity (Ref: non-teaching)											
Low						0.114	0.067	1.120	0.113	0.066	1.120
Medium						-0.057	0.075	0.945	-0.054	0.075	0.948
High						0.198	0.109	1.219	0.199	0.109	1.220
Hospital location (Ref: Rural)											
Micro/Division						-0.276*	0.132	0.759*	-0.275*	0.131	0.760*
Metro						-0.316*	0.124	0.729*	-0.313*	0.124	0.731*
Disproportionate Share Hospital (DSH) Index						0.234	0.192	1.264	0.214	0.193	1.239
Mean number of Elixhauser comorbid conditions						-0.067	0.057	0.936	-0.069	0.057	0.933
Proportion of patients with prior hospitalization for both AMI and other conditions						0.002	0.663	1.002	0.061	0.664	1.062
Hospital AMI Volume						-0.000	0.000	1.000	-0.000	0.000	1.000
PQM (%): Aspirin at Arrival						-0.010	0.008	0.990	-0.016	0.010	0.984
									0.000	0.000	1.000
Interaction (Volume × PQM)											
Random effects											

Hospital (intercept)											
Variance between hospitals	0.040***		0.029***			0.020*			0.020*		
ICC	0.012		0.009			0.006			0.006		
MOR	1.209		1.175			1.145			1.143		
n: level-1 (patients)	21628		21628			21628			21628		
n: level-2 (hospitals)	379		379			379			379		
AIC	18621		18259			18267			18268		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3 = 3.29$.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 10:
Association of AMI-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (Aspirin at Discharge)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.003	0.003	1.003	0.003	0.003	1.003	0.003	0.003	1.003
Female			0.002	0.041	1.002	0.003	0.041	1.003	0.003	0.041	1.003
Race (Ref: White)											
Black			0.069	0.088	1.071	0.050	0.089	1.051	0.049	0.089	1.050
Hispanic			0.016	0.069	1.017	0.001	0.071	1.001	0.003	0.071	1.003
Others			-0.032	0.084	0.969	-0.054	0.087	0.947	-0.056	0.087	0.946
Disposition (Ref=Routine)											
Home Health Care			0.271***	0.056	1.311***	0.272***	0.056	1.312***	0.271***	0.056	1.312***
Nursing Home			0.634***	0.052	1.885***	0.631***	0.052	1.879***	0.630***	0.052	1.878***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.064	0.054	0.938	-0.046	0.054	0.955	-0.048	0.054	0.953
3rd quartile			-0.049	0.056	0.952	-0.029	0.057	0.971	-0.030	0.057	0.970
4th quartile			-0.085	0.059	0.919	-0.057	0.061	0.945	-0.056	0.061	0.946
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than AMI			0.082	0.261	1.085	0.073	0.261	1.076	0.075	0.261	1.078
Prior admission (1y) for AMI			0.304***	0.041	1.355***	0.305***	0.041	1.357***	0.305***	0.041	1.357***
Prior admission (1y) for both AMI and other conditions			0.408***	0.097	1.503***	0.405***	0.098	1.499***	0.405***	0.098	1.499***
AMI location: Anterior			0.055	0.069	1.057	0.057	0.069	1.059	0.058	0.069	1.059

AMI location: Other			0.047	0.062	1.049	0.052	0.062	1.053	0.052	0.062	1.054
Procedure											
CABG			-0.268***	0.077	0.765***	-0.253**	0.078	0.776**	-0.253**	0.078	0.776**
PTCA			0.101*	0.048	1.106*	0.117*	0.049	1.124*	0.117*	0.049	1.124*
Comorbidities											
AIDS			1.360	0.746	3.898	1.340	0.744	3.819	1.342	0.744	3.828
Alcohol abuse			0.057	0.156	1.059	0.057	0.156	1.059	0.057	0.156	1.058
Deficiency anemias			0.035	0.046	1.036	0.036	0.046	1.037	0.036	0.046	1.037
Rheumatoid arthritis			-0.033	0.116	0.968	-0.026	0.116	0.974	-0.025	0.116	0.975
Chronic blood loss anemia			-0.210	0.136	0.811	-0.208	0.136	0.812	-0.209	0.136	0.811
Congest Heart Failure			-0.286	0.263	0.751	-0.292	0.263	0.747	-0.294	0.263	0.745
Chronic pulmonary disease			0.168***	0.043	1.183***	0.169***	0.044	1.184***	0.170***	0.044	1.185***
Coagulopathy			-0.139	0.094	0.870	-0.136	0.094	0.873	-0.136	0.094	0.873
Depression			-0.011	0.074	0.989	-0.009	0.074	0.991	-0.009	0.074	0.991
Diabetes, uncomplicated			0.142**	0.044	1.153**	0.141**	0.044	1.152**	0.141**	0.044	1.152**
Diabetes w/ chronic complications			0.238**	0.077	1.269**	0.241**	0.077	1.272**	0.241**	0.077	1.273**
Drug abuse			-0.249	0.368	0.780	-0.250	0.368	0.779	-0.250	0.368	0.779
Hypertension			0.053	0.044	1.054	0.051	0.044	1.053	0.052	0.044	1.053
Hypothyroidism			0.038	0.055	1.039	0.039	0.055	1.040	0.038	0.055	1.039
Liver disease			0.013	0.194	1.013	0.012	0.193	1.012	0.012	0.193	1.012
Lymphoma			0.216	0.409	1.241	0.228	0.409	1.256	0.223	0.409	1.250
Fluid and electrolyte disorders			0.050	0.047	1.051	0.053	0.047	1.055	0.053	0.047	1.055
Metastatic cancer			-1.171	0.600	0.310	-1.195*	0.601	0.303*	-1.197*	0.601	0.302*
Other neurological disorders			-0.114	0.067	0.892	-0.113	0.067	0.893	-0.114	0.067	0.893
Obesity			-0.057	0.073	0.945	-0.052	0.073	0.949	-0.051	0.073	0.950
Paralysis			0.019	0.108	1.019	0.021	0.108	1.021	0.021	0.108	1.021
Peripheral vascular disorders			0.071	0.052	1.073	0.072	0.052	1.075	0.073	0.052	1.076
Psychoses			0.065	0.120	1.067	0.066	0.120	1.068	0.066	0.120	1.068
Pulmonary circulation disorders			0.309	0.841	1.362	0.303	0.841	1.354	0.301	0.841	1.351
Renal failure			0.183***	0.048	1.201***	0.184***	0.048	1.202***	0.183***	0.048	1.201***

Solid tumor without metastasis			-0.199	0.144	0.819	-0.195	0.144	0.823	-0.196	0.144	0.822
Peptic ulcer disease			1.524*	0.730	4.591*	1.557*	0.731	4.744*	1.558*	0.732	4.751*
Valvular disease			-0.216	0.412	0.805	-0.213	0.411	0.808	-0.208	0.411	0.812
Weight loss			-0.099	0.128	0.906	-0.094	0.128	0.911	-0.094	0.128	0.911
Level 2: Hospital Characteristics											
California (Ref: Florida)						0.082	0.058	1.086	0.088	0.058	1.092
Ownership (Ref: Public)											
Private, not-for-profit						-0.008	0.069	0.992	-0.014	0.069	0.987
Private, for-profit						-0.075	0.082	0.928	-0.078	0.082	0.925
System affiliation						0.061	0.055	1.063	0.058	0.055	1.060
Cardiac catherization facility						-0.091	0.108	0.913	-0.077	0.109	0.925
Magnet hospital						-0.127	0.089	0.881	-0.140	0.090	0.869
Teaching intensity (Ref: non-teaching)											
Low						0.117	0.067	1.124	0.122	0.067	1.130
Medium						-0.065	0.076	0.937	-0.057	0.076	0.944
High						0.199	0.110	1.220	0.201	0.110	1.222
Hospital location (Ref: Rural)											
Micro/Division						-0.258	0.138	0.772	-0.251	0.138	0.778
Metro						-0.287*	0.131	0.751*	-0.277*	0.131	0.758*
Disproportionate Share Hospital (DSH) Index						0.236	0.196	1.266	0.227	0.196	1.255
Mean number of Elixhauser comorbid conditions						-0.033	0.058	0.967	-0.030	0.058	0.970
Proportion of patients with prior hospitalization for both AMI and other conditions						-0.134	0.707	0.874	-0.075	0.707	0.927
Hospital AMI Volume						-0.000	0.000	1.000	-0.000	0.000	1.000
PQM (%): Aspirin at Discharge						-0.003	0.005	0.997	-0.006	0.006	0.994
									0.000	0.000	1.000
Interaction (Volume × PQM)											

Random effects											
Hospital (intercept)											
Variance between hospitals	0.040***		0.029***			0.021**			0.021*		
ICC	0.012		0.009			0.006			0.006		
MOR	1.210		1.178			1.150			1.146		
n: level-1 (patients)	21301		21301			21301			21301		
n: level-2 (hospitals)	340		340			340			340		
AIC	18310		17959			17970			17971		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3 = 3.29$.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 11:
Association of AMI-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (Beta Blocker at Arrival)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.003	0.003	1.003	0.004	0.003	1.004	0.004	0.003	1.004
Female			0.004	0.041	1.004	0.005	0.041	1.005	0.005	0.041	1.006
Race (Ref: White)											
Black			0.076	0.088	1.079	0.060	0.088	1.062	0.059	0.088	1.061
Hispanic			0.023	0.069	1.023	0.008	0.071	1.008	0.010	0.071	1.010
Others			-0.043	0.084	0.958	-0.063	0.086	0.939	-0.062	0.086	0.940
Disposition (Ref=Routine)											
Home Health Care			0.262***	0.055	1.299***	0.263***	0.055	1.301***	0.262***	0.055	1.300***
Nursing Home			0.627***	0.051	1.873***	0.625***	0.052	1.868***	0.624***	0.052	1.866***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.067	0.053	0.936	-0.047	0.053	0.954	-0.047	0.053	0.954
3rd quartile			-0.049	0.055	0.953	-0.025	0.056	0.975	-0.026	0.056	0.974
4th quartile			-0.085	0.059	0.918	-0.054	0.060	0.947	-0.054	0.060	0.948
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than AMI			0.074	0.261	1.077	0.066	0.261	1.068	0.066	0.261	1.069
Prior admission (1y) for AMI			0.302***	0.041	1.352***	0.303***	0.041	1.354***	0.304***	0.041	1.355***
Prior admission (1y) for both AMI and other conditions			0.393***	0.096	1.481***	0.386***	0.098	1.471***	0.386***	0.098	1.471***
AMI location: Anterior			0.047	0.068	1.048	0.047	0.068	1.048	0.046	0.068	1.048

AMI location: Other			0.051	0.062	1.053	0.055	0.062	1.057	0.054	0.062	1.056
Procedure											
CABG			-0.275***	0.077	0.759***	-0.259***	0.078	0.771***	-0.258***	0.078	0.772***
PTCA			0.097*	0.048	1.102*	0.114*	0.049	1.121*	0.118*	0.049	1.125*
Comorbidities											
AIDS			1.354	0.746	3.873	1.340	0.744	3.817	1.347	0.744	3.848
Alcohol abuse			0.092	0.154	1.097	0.092	0.154	1.096	0.091	0.154	1.096
Deficiency anemias			0.029	0.045	1.030	0.031	0.045	1.032	0.031	0.045	1.032
Rheumatoid arthritis			-0.054	0.116	0.947	-0.048	0.116	0.953	-0.046	0.116	0.955
Chronic blood loss anemia			-0.217	0.136	0.805	-0.214	0.136	0.808	-0.213	0.136	0.808
Congest Heart Failure			-0.182	0.254	0.833	-0.187	0.254	0.830	-0.191	0.254	0.826
Chronic pulmonary disease			0.173***	0.043	1.188***	0.175***	0.043	1.191***	0.175***	0.043	1.191***
Coagulopathy			-0.150	0.094	0.861	-0.145	0.094	0.865	-0.144	0.094	0.866
Depression			-0.022	0.073	0.978	-0.019	0.073	0.981	-0.019	0.073	0.981
Diabetes, uncomplicated			0.143**	0.044	1.153**	0.142**	0.044	1.153**	0.142**	0.044	1.153**
Diabetes w/ chronic complications			0.231**	0.077	1.260**	0.233**	0.077	1.262**	0.232**	0.077	1.261**
Drug abuse			-0.260	0.369	0.771	-0.256	0.368	0.774	-0.259	0.368	0.772
Hypertension			0.049	0.044	1.051	0.049	0.044	1.051	0.050	0.044	1.051
Hypothyroidism			0.038	0.055	1.039	0.040	0.055	1.040	0.039	0.055	1.040
Liver disease			0.031	0.191	1.032	0.030	0.191	1.031	0.029	0.191	1.030
Lymphoma			0.207	0.409	1.230	0.218	0.409	1.243	0.218	0.409	1.244
Fluid and electrolyte disorders			0.055	0.046	1.056	0.058	0.046	1.060	0.058	0.046	1.060
Metastatic cancer			-1.234*	0.599	0.291*	-1.251*	0.599	0.286*	-1.252*	0.599	0.286*
Other neurological disorders			-0.121	0.067	0.886	-0.119	0.067	0.888	-0.119	0.067	0.888
Obesity			-0.054	0.072	0.947	-0.049	0.072	0.953	-0.048	0.072	0.954
Paralysis			0.018	0.107	1.018	0.021	0.107	1.021	0.021	0.107	1.022
Peripheral vascular disorders			0.074	0.052	1.076	0.075	0.052	1.078	0.076	0.052	1.079
Psychoses			0.087	0.119	1.091	0.091	0.119	1.095	0.090	0.119	1.094
Pulmonary circulation disorders			0.318	0.839	1.375	0.312	0.838	1.366	0.316	0.838	1.372
Renal failure			0.191***	0.048	1.210***	0.192***	0.048	1.212***	0.192***	0.048	1.212***

Solid tumor without metastasis			-0.168	0.141	0.845	-0.165	0.141	0.848	-0.164	0.141	0.849
Peptic ulcer disease			1.521*	0.730	4.577*	1.555*	0.731	4.735*	1.544*	0.732	4.681*
Valvular disease			-0.314	0.410	0.731	-0.309	0.410	0.735	-0.309	0.410	0.734
Weight loss			-0.112	0.127	0.894	-0.107	0.127	0.898	-0.107	0.127	0.899
Level 2: Hospital Characteristics											
California (Ref: Florida)						0.078	0.057	1.081	0.082	0.057	1.085
Ownership (Ref: Public)											
Private, not-for-profit						-0.011	0.068	0.989	-0.002	0.069	0.998
Private, for-profit						-0.069	0.083	0.934	-0.067	0.083	0.935
System affiliation						0.062	0.056	1.064	0.052	0.056	1.053
Cardiac catherization facility						-0.114	0.096	0.893	-0.103	0.097	0.902
Magnet hospital						-0.131	0.088	0.878	-0.146	0.089	0.864
Teaching intensity (Ref: non-teaching)											
Low						0.119	0.067	1.126	0.117	0.067	1.124
Medium						-0.065	0.075	0.938	-0.067	0.075	0.935
High						0.187	0.109	1.206	0.192	0.109	1.212
Hospital location (Ref: Rural)											
Micro/Division						-0.300*	0.131	0.741*	-0.309*	0.131	0.734*
Metro						-0.325**	0.125	0.723**	-0.329**	0.124	0.720**
Disproportionate Share Hospital (DSH) Index						0.245	0.194	1.277	0.223	0.194	1.250
Mean number of Elixhauser comorbid conditions						-0.045	0.058	0.956	-0.046	0.057	0.955
Proportion of patients with prior hospitalization for both AMI and other conditions						0.009	0.667	1.009	0.050	0.666	1.051
Hospital AMI Volume						-0.000	0.000	1.000	-0.000	0.000	1.000
PQM (%): Beta Blocker at Arrival						-0.001	0.004	0.999	-0.006	0.006	0.994
											1.000
Interaction (Volume × PQM)											

Random effects											
Hospital (intercept)											
Variance between hospitals	0.040***		0.029***			0.021**			0.020*		
ICC	0.012		0.009			0.006			0.006		
MOR	1.210		1.176			1.147			1.144		
n: level-1 (patients)	21548		21548			21548			21548		
n: level-2 (hospitals)	369		369			369			369		
AIC	18566		18206			18215			18215		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3 = 3.29$.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 12:
Association of AMI-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (Beta Blocker at Discharge)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.003	0.003	1.003	0.003	0.003	1.003	0.003	0.003	1.003
Female			0.006	0.041	1.006	0.006	0.041	1.006	0.006	0.041	1.006
Race (Ref: White)											
Black			0.080	0.088	1.083	0.060	0.089	1.062	0.061	0.088	1.062
Hispanic			0.011	0.069	1.011	-0.002	0.072	0.998	0.001	0.072	1.001
Others			-0.035	0.085	0.965	-0.054	0.087	0.948	-0.052	0.087	0.949
Disposition (Ref=Routine)											
Home Health Care			0.269***	0.056	1.309***	0.270***	0.056	1.310***	0.270***	0.056	1.310***
Nursing Home			0.630***	0.052	1.878***	0.628***	0.052	1.873***	0.627***	0.052	1.872***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.067	0.054	0.935	-0.049	0.054	0.952	-0.051	0.054	0.950
3rd quartile			-0.045	0.056	0.956	-0.025	0.057	0.975	-0.026	0.057	0.974
4th quartile			-0.090	0.059	0.914	-0.061	0.061	0.941	-0.060	0.061	0.941
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than AMI			0.085	0.261	1.089	0.075	0.261	1.078	0.077	0.261	1.080
Prior admission (1y) for AMI			0.306***	0.041	1.358***	0.307***	0.041	1.360***	0.308***	0.041	1.360***
Prior admission (1y) for both AMI and other conditions			0.409***	0.097	1.505***	0.405***	0.098	1.500***	0.405***	0.098	1.500***
AMI location: Anterior			0.054	0.069	1.055	0.055	0.069	1.057	0.056	0.069	1.057

AMI location: Other			0.048	0.062	1.049	0.052	0.062	1.053	0.052	0.062	1.053
Procedure											
CABG			-0.262***	0.077	0.770***	-0.252**	0.078	0.777**	-0.252**	0.078	0.778**
PTCA			0.105*	0.048	1.111*	0.116*	0.049	1.123*	0.117*	0.049	1.124*
Comorbidities											
AIDS			1.356	0.746	3.879	1.341	0.745	3.824	1.348	0.744	3.851
Alcohol abuse			0.061	0.156	1.062	0.060	0.156	1.062	0.060	0.156	1.062
Deficiency anemias			0.034	0.046	1.035	0.036	0.046	1.037	0.036	0.046	1.037
Rheumatoid arthritis			-0.031	0.116	0.970	-0.023	0.117	0.977	-0.022	0.117	0.978
Chronic blood loss anemia			-0.201	0.136	0.818	-0.199	0.136	0.819	-0.200	0.136	0.819
Congest Heart Failure			-0.274	0.264	0.760	-0.279	0.263	0.756	-0.281	0.263	0.755
Chronic pulmonary disease			0.165***	0.043	1.180***	0.167***	0.044	1.182***	0.168***	0.044	1.183***
Coagulopathy			-0.136	0.094	0.872	-0.133	0.094	0.876	-0.132	0.094	0.877
Depression			-0.011	0.074	0.989	-0.009	0.074	0.991	-0.009	0.074	0.991
Diabetes, uncomplicated			0.142**	0.044	1.153**	0.141**	0.044	1.152**	0.141**	0.044	1.152**
Diabetes w/ chronic complications			0.230**	0.077	1.258**	0.234**	0.077	1.264**	0.234**	0.077	1.264**
Drug abuse			-0.225	0.369	0.798	-0.225	0.369	0.799	-0.226	0.369	0.797
Hypertension			0.050	0.044	1.051	0.049	0.044	1.050	0.049	0.044	1.051
Hypothyroidism			0.044	0.055	1.045	0.045	0.055	1.046	0.044	0.055	1.045
Liver disease			0.016	0.194	1.016	0.016	0.193	1.016	0.015	0.193	1.015
Lymphoma			0.220	0.409	1.246	0.229	0.409	1.257	0.227	0.409	1.255
Fluid and electrolyte disorders			0.045	0.047	1.046	0.050	0.047	1.051	0.050	0.047	1.051
Metastatic cancer			-1.206*	0.599	0.299*	-1.228*	0.600	0.293*	-1.231*	0.600	0.292*
Other neurological disorders			-0.108	0.067	0.898	-0.106	0.067	0.899	-0.107	0.067	0.899
Obesity			-0.053	0.073	0.948	-0.049	0.073	0.953	-0.048	0.073	0.953
Paralysis			0.015	0.108	1.016	0.020	0.108	1.020	0.019	0.108	1.019
Peripheral vascular disorders			0.071	0.052	1.074	0.073	0.052	1.076	0.073	0.052	1.076
Psychoses			0.075	0.120	1.078	0.077	0.120	1.081	0.078	0.120	1.081
Pulmonary circulation disorders			0.305	0.841	1.356	0.296	0.840	1.345	0.298	0.840	1.347
Renal failure			0.187***	0.048	1.205***	0.188***	0.048	1.207***	0.188***	0.048	1.206***

Solid tumor without metastasis			-0.198	0.144	0.820	-0.194	0.144	0.823	-0.194	0.144	0.823
Peptic ulcer disease			1.527*	0.730	4.603*	1.555*	0.731	4.737*	1.566*	0.732	4.789*
Valvular disease			-0.221	0.412	0.801	-0.219	0.411	0.803	-0.215	0.411	0.806
Weight loss			-0.080	0.128	0.923	-0.073	0.128	0.929	-0.072	0.128	0.931
Level 2: Hospital Characteristics											
California (Ref: Florida)						0.098	0.058	1.103	0.101	0.058	1.106
Ownership (Ref: Public)											
Private, not-for-profit						-0.018	0.069	0.983	-0.013	0.068	0.987
Private, for-profit						-0.081	0.083	0.923	-0.075	0.083	0.927
System affiliation						0.069	0.056	1.071	0.058	0.057	1.060
Cardiac catherization facility						-0.062	0.109	0.940	-0.043	0.111	0.958
Magnet hospital						-0.124	0.088	0.884	-0.132	0.088	0.876
Teaching intensity (Ref: non-teaching)											
Low						0.117	0.067	1.124	0.121	0.067	1.128
Medium						-0.062	0.075	0.940	-0.054	0.075	0.947
High						0.197	0.110	1.217	0.199	0.109	1.221
Hospital location (Ref: Rural)											
Micro/Division						-0.266	0.137	0.766	-0.270*	0.137	0.763*
Metro						-0.293*	0.131	0.746*	-0.292*	0.131	0.747*
Disproportionate Share Hospital (DSH) Index						0.238	0.196	1.268	0.227	0.196	1.255
Mean number of Elixhauser comorbid conditions						-0.055	0.058	0.947	-0.054	0.058	0.948
Proportion of patients with prior hospitalization for both AMI and other conditions						-0.106	0.707	0.899	-0.048	0.707	0.954
Hospital AMI Volume						-0.000	0.000	1.000	-0.000	0.000	1.000
PQM (%): Beta Blocker at Discharge						-0.003	0.005	0.997	-0.007	0.007	0.993
									0.000	0.000	1.000
Interaction (Volume × PQM)											

Random effects											
Hospital (intercept)											
Variance between hospitals	0.040***		0.029***			0.021**			0.020*		
ICC	0.011		0.009			0.006			0.006		
MOR	1.208		1.177			1.148			1.144		
n: level-1 (patients)	21328		21328			21328			21328		
n: level-2 (hospitals)	344		344			344			344		
AIC	18316		17965			17976			17977		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3 = 3.29$.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 13:
Association of AMI-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (PCI Within 90m of Arrival)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.003	0.003	1.003	0.003	0.003	1.004	0.003	0.003	1.004
Female			0.001	0.047	1.001	0.004	0.047	1.004	0.004	0.047	1.004
Race (Ref: White)											
Black			0.015	0.103	1.015	-0.030	0.103	0.971	-0.029	0.103	0.971
Hispanic			-0.020	0.080	0.980	-0.029	0.082	0.971	-0.027	0.082	0.973
Others			0.028	0.098	1.029	0.016	0.100	1.017	0.014	0.100	1.014
Disposition (Ref=Routine)											
Home Health Care			0.341***	0.063	1.406***	0.342***	0.063	1.407***	0.341***	0.063	1.407***
Nursing Home			0.683***	0.061	1.980***	0.686***	0.061	1.985***	0.685***	0.061	1.984***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.063	0.061	0.939	-0.044	0.061	0.957	-0.046	0.061	0.955
3rd quartile			-0.048	0.064	0.953	-0.021	0.064	0.980	-0.023	0.064	0.977
4th quartile			-0.100	0.067	0.905	-0.072	0.068	0.931	-0.076	0.068	0.927
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than AMI											
Prior admission (1y) for AMI			0.321***	0.047	1.379***	0.315***	0.047	1.371***	0.316***	0.047	1.371***
Prior admission (1y) for both AMI and other conditions			0.416**	0.133	1.517**	0.389**	0.134	1.476**	0.390**	0.134	1.477**
AMI location: Anterior			0.035	0.076	1.036	0.045	0.076	1.046	0.046	0.076	1.047

AMI location: Other			0.081	0.067	1.084	0.090	0.067	1.095	0.091	0.067	1.095
Procedure											
CABG			-0.245**	0.082	0.783**	-0.250**	0.082	0.778**	-0.250**	0.082	0.779**
PTCA			0.129*	0.053	1.137*	0.130*	0.053	1.138*	0.129*	0.053	1.138*
Comorbidities											
AIDS											
Alcohol abuse			-0.055	0.183	0.946	-0.058	0.183	0.943	-0.057	0.183	0.944
Deficiency anemias			0.061	0.053	1.063	0.063	0.053	1.065	0.062	0.053	1.064
Rheumatoid arthritis			-0.099	0.133	0.906	-0.086	0.133	0.917	-0.086	0.133	0.918
Chronic blood loss anemia			-0.066	0.151	0.936	-0.065	0.151	0.937	-0.066	0.151	0.936
Congest Heart Failure			-0.388	0.341	0.678	-0.414	0.341	0.661	-0.416	0.341	0.660
Chronic pulmonary disease			0.144**	0.050	1.155**	0.153**	0.050	1.165**	0.153**	0.050	1.166**
Coagulopathy			-0.133	0.105	0.876	-0.132	0.105	0.877	-0.132	0.105	0.876
Depression			-0.102	0.088	0.903	-0.103	0.089	0.902	-0.104	0.089	0.901
Diabetes, uncomplicated			0.158**	0.051	1.171**	0.155**	0.051	1.168**	0.156**	0.051	1.169**
Diabetes w/ chronic complications			0.237**	0.091	1.267**	0.249**	0.091	1.283**	0.249**	0.091	1.282**
Drug abuse			0.147	0.378	1.158	0.160	0.378	1.174	0.159	0.377	1.172
Hypertension			0.029	0.050	1.030	0.024	0.051	1.024	0.023	0.051	1.024
Hypothyroidism			-0.006	0.064	0.994	-0.004	0.064	0.996	-0.004	0.064	0.996
Liver disease			-0.081	0.237	0.922	-0.083	0.237	0.920	-0.084	0.237	0.920
Lymphoma			0.321	0.445	1.379	0.361	0.446	1.435	0.359	0.445	1.431
Fluid and electrolyte disorders			0.057	0.054	1.059	0.063	0.054	1.065	0.063	0.054	1.065
Metastatic cancer			-0.746	0.610	0.474	-0.806	0.610	0.446	-0.803	0.610	0.448
Other neurological disorders			-0.083	0.079	0.920	-0.083	0.079	0.920	-0.083	0.079	0.921
Obesity			-0.046	0.081	0.955	-0.041	0.081	0.960	-0.041	0.081	0.960
Paralysis			0.056	0.128	1.058	0.060	0.128	1.062	0.059	0.128	1.061
Peripheral vascular disorders			0.089	0.059	1.093	0.091	0.059	1.095	0.091	0.059	1.095
Psychoses			0.147	0.137	1.158	0.147	0.137	1.158	0.147	0.137	1.158
Pulmonary circulation disorders			0.997	0.931	2.711	1.004	0.929	2.729	1.002	0.929	2.725
Renal failure			0.165**	0.056	1.179**	0.167**	0.056	1.181**	0.167**	0.056	1.182**

Solid tumor without metastasis			-0.228	0.166	0.796	-0.227	0.165	0.797	-0.226	0.165	0.798
Peptic ulcer disease			1.241	0.789	3.460	1.216	0.788	3.374	1.219	0.788	3.383
Valvular disease			-0.292	0.512	0.747	-0.292	0.510	0.747	-0.288	0.510	0.750
Weight loss			-0.025	0.150	0.975	-0.005	0.150	0.995	-0.006	0.150	0.994
Level 2: Hospital Characteristics											
California (Ref: Florida)						0.138*	0.064	1.148*	0.144*	0.065	1.154*
Ownership (Ref: Public)											
Private, not-for-profit						0.019	0.074	1.019	0.029	0.076	1.029
Private, for-profit						-0.066	0.091	0.936	-0.057	0.092	0.945
System affiliation						0.137*	0.062	1.147*	0.144*	0.062	1.155*
Cardiac catherization facility											
Magnet hospital						-0.161	0.085	0.851	-0.178*	0.089	0.837*
Teaching intensity (Ref: non-teaching)											
Low						0.121	0.068	1.129	0.125	0.067	1.133
Medium						-0.055	0.078	0.947	-0.060	0.078	0.942
High						0.251*	0.116	1.286*	0.275*	0.122	1.316*
Hospital location (Ref: Rural)											
Micro/Division						-0.168	0.228	0.846	-0.177	0.226	0.838
Metro						-0.238	0.225	0.788	-0.248	0.223	0.781
Disproportionate Share Hospital (DSH) Index						0.304	0.257	1.355	0.302	0.255	1.352
Mean number of Elixhauser comorbid conditions						-0.122	0.070	0.885	-0.120	0.070	0.887
Proportion of patients with prior hospitalization for both AMI and other conditions						0.851	1.102	2.343	0.857	1.098	2.356
Hospital AMI Volume						-0.000	0.000	1.000	-0.000	0.000	1.000
PQM (%):PCI Within 90m of Arrival						-0.004**	0.001	0.996**	-0.002	0.003	0.998
Interaction (Volume × PQM)									-0.000	0.000	1.000
Random effects											

Hospital (intercept)											
Variance between hospitals	0.023**		0.018*			0.005			0.003		
ICC	0.007		0.006			0.001			0.001		
MOR	1.157		1.138			1.066			1.058		
n: level-1 (patients)	16654		16654			16654			16654		
n: level-2 (hospitals)	168		168			168			168		
AIC	14087		13811			13807			13809		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3 = 3.29$.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 14:
Association of PN-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (Admission Composite Measure)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.003	0.002	1.003	0.003	0.002	1.003	0.003	0.002	1.003
Female			-0.128***	0.034	0.880***	-0.132***	0.034	0.876***	-0.132***	0.034	0.876***
Race (Ref: White)											
Black			0.076	0.076	1.079	0.049	0.077	1.051	0.049	0.077	1.050
Hispanic			0.041	0.056	1.041	-0.006	0.057	0.995	-0.005	0.057	0.995
Others			-0.070	0.071	0.933	-0.146*	0.072	0.864*	-0.146*	0.072	0.865*
Disposition (Ref=Routine)											
Home Health Care			0.287***	0.049	1.332***	0.298***	0.049	1.347***	0.298***	0.049	1.347***
Nursing Home			0.758***	0.040	2.134***	0.754***	0.040	2.125***	0.754***	0.040	2.125***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.063	0.047	0.939	-0.061	0.047	0.941	-0.061	0.047	0.941
3rd quartile			-0.006	0.049	0.994	0.004	0.049	1.004	0.004	0.049	1.004
4th quartile			-0.018	0.054	0.982	-0.005	0.055	0.995	-0.005	0.055	0.995
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than PN			0.095	0.170	1.100	0.080	0.170	1.083	0.080	0.170	1.083
Prior admission (1y) for PN			0.366***	0.036	1.442***	0.365***	0.036	1.441***	0.365***	0.036	1.441***
Prior admission (1y) for both PN and other conditions			0.642***	0.057	1.901***	0.617***	0.058	1.853***	0.617***	0.058	1.853***
Comorbidities											

AIDS											
Alcohol abuse			0.207	0.125	1.231	0.200	0.125	1.222	0.200	0.125	1.221
Deficiency anemias			0.027	0.037	1.028	0.028	0.037	1.029	0.028	0.037	1.029
Rheumatoid arthritis			0.226**	0.082	1.253**	0.238**	0.082	1.268**	0.238**	0.082	1.268**
Chronic blood loss anemia			-0.011	0.158	0.989	0.004	0.158	1.004	0.004	0.158	1.004
Congest Heart Failure			0.198***	0.037	1.219***	0.190***	0.036	1.209***	0.190***	0.036	1.209***
Chronic pulmonary disease			0.160***	0.034	1.173***	0.171***	0.034	1.187***	0.171***	0.034	1.187***
Coagulopathy			-0.174	0.098	0.840	-0.164	0.097	0.849	-0.164	0.097	0.849
Depression			-0.095	0.054	0.909	-0.086	0.054	0.917	-0.086	0.054	0.917
Diabetes, uncomplicated			0.066	0.039	1.068	0.069	0.039	1.072	0.069	0.039	1.072
Diabetes w/ chronic complications			0.121	0.076	1.129	0.119	0.076	1.127	0.119	0.076	1.127
Drug abuse			0.136	0.234	1.146	0.130	0.233	1.139	0.130	0.233	1.139
Hypertension			-0.033	0.036	0.968	-0.019	0.036	0.981	-0.019	0.036	0.981
Hypothyroidism			-0.008	0.044	0.992	-0.004	0.044	0.996	-0.004	0.044	0.996
Liver disease			0.172	0.135	1.188	0.174	0.135	1.190	0.174	0.135	1.190
Lymphoma			-0.279	0.239	0.756	-0.257	0.239	0.774	-0.257	0.239	0.774
Fluid and electrolyte disorders			0.050	0.034	1.051	0.055	0.034	1.057	0.055	0.034	1.057
Metastatic cancer			0.094	0.269	1.098	0.103	0.269	1.109	0.104	0.269	1.109
Other neurological disorders			0.067	0.045	1.069	0.067	0.045	1.069	0.067	0.045	1.069
Obesity			-0.090	0.075	0.914	-0.074	0.075	0.929	-0.074	0.075	0.929
Paralysis			0.016	0.088	1.016	0.010	0.088	1.010	0.010	0.088	1.010
Peripheral vascular disorders			0.066	0.058	1.069	0.082	0.058	1.086	0.082	0.058	1.086
Psychoses			0.122	0.077	1.130	0.103	0.077	1.108	0.103	0.077	1.108
Pulmonary circulation disorders			0.077	0.075	1.080	0.094	0.075	1.099	0.094	0.075	1.099
Renal failure			0.121**	0.045	1.129**	0.125**	0.045	1.133**	0.125**	0.045	1.133**
Solid tumor without metastasis			-0.044	0.091	0.957	-0.038	0.091	0.962	-0.038	0.091	0.962
Peptic ulcer disease			0.628	0.527	1.874	0.612	0.526	1.844	0.612	0.526	1.844
Valvular disease			-0.024	0.055	0.976	-0.005	0.055	0.995	-0.005	0.055	0.995
Weight loss			0.173*	0.072	1.189*	0.171*	0.072	1.187*	0.171*	0.072	1.187*

Level 2: Hospital Characteristics											
California (Ref: Florida)						-0.143**	0.052	0.867**	-0.142**	0.053	0.867**
Ownership (Ref: Public)											
Private, not-for-profit						0.043	0.067	1.044	0.043	0.067	1.044
Private, for-profit						-0.047	0.078	0.954	-0.048	0.078	0.954
System affiliation						0.072	0.054	1.075	0.072	0.054	1.074
Cardiac catherization facility						-0.086	0.061	0.917	-0.086	0.062	0.918
Magnet hospital						-0.184	0.099	0.832	-0.186	0.101	0.830
Teaching intensity (Ref: non-teaching)											
Low						0.063	0.069	1.065	0.063	0.069	1.065
Medium						-0.066	0.075	0.936	-0.066	0.075	0.936
High						0.042	0.111	1.043	0.040	0.112	1.041
Hospital location (Ref: Rural)											
Micro/Division						0.025	0.105	1.025	0.025	0.105	1.025
Metro						-0.091	0.098	0.913	-0.091	0.098	0.913
Disproportionate Share Hospital (DSH) Index						-0.035	0.162	0.966	-0.036	0.162	0.965
Mean number of Elixhauser comorbid conditions						-0.104*	0.049	0.901*	-0.104*	0.049	0.901*
Proportion of patients with prior hospitalization for both PN and other conditions						2.238***	0.680	9.376***	2.237**	0.680	9.368**
Hospital PN Volume						-0.000	0.000	1.000	-0.000	0.000	1.000
PQM (%): Admission Composite Measure						-0.020**	0.007	0.980**	-0.021	0.011	0.979
Interaction (Volume × PQM)									0.000	0.000	1.000
Random effects											
Hospital (intercept)											
Variance between hospitals	0.111***		0.096***			0.058***			0.058***		
ICC	0.033		0.028			0.017			0.017		
MOR	1.375		1.345			1.259			1.259		

n: level-1 (patients)	36384		36384			36384			36384		
n: level-2 (hospitals)	426		426			426			426		
AIC	27104		26227			26188			26190		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3$ =3.29.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 15:
Association of PN-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (Discharge Composite Measure)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.003	0.002	1.003	0.003	0.002	1.003	0.003	0.002	1.003
Female			-0.128***	0.034	0.880***	-0.132***	0.034	0.877***	-0.132***	0.034	0.877***
Race (Ref: White)											
Black			0.076	0.076	1.079	0.054	0.077	1.056	0.054	0.077	1.056
Hispanic			0.037	0.057	1.038	-0.012	0.058	0.988	-0.011	0.058	0.989
Others			-0.070	0.071	0.933	-0.150*	0.072	0.861*	-0.146*	0.072	0.865*
Disposition (Ref=Routine)											
Home Health Care			0.287***	0.049	1.332***	0.297***	0.049	1.346***	0.298***	0.049	1.347***
Nursing Home			0.760***	0.040	2.138***	0.755***	0.040	2.128***	0.756***	0.040	2.129***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.065	0.047	0.937	-0.066	0.047	0.936	-0.066	0.047	0.936
3rd quartile			-0.007	0.049	0.993	-0.005	0.049	0.995	-0.003	0.049	0.997
4th quartile			-0.018	0.054	0.982	-0.013	0.055	0.987	-0.011	0.055	0.989
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than PN			0.096	0.170	1.101	0.084	0.170	1.087	0.083	0.170	1.087
Prior admission (1y) for PN			0.367***	0.036	1.443***	0.365***	0.036	1.440***	0.364***	0.036	1.440***
Prior admission (1y) for both PN and other conditions			0.644***	0.057	1.904***	0.619***	0.058	1.857***	0.619***	0.058	1.857***
Comorbidities											

AIDS											
Alcohol abuse			0.207	0.125	1.230	0.200	0.125	1.221	0.198	0.125	1.219
Deficiency anemias			0.027	0.037	1.027	0.028	0.037	1.028	0.028	0.037	1.028
Rheumatoid arthritis			0.227**	0.082	1.254**	0.236**	0.082	1.266**	0.235**	0.082	1.265**
Chronic blood loss anemia			-0.011	0.158	0.989	0.004	0.158	1.004	0.005	0.158	1.005
Congest Heart Failure			0.198***	0.037	1.219***	0.192***	0.037	1.211***	0.192***	0.037	1.211***
Chronic pulmonary disease			0.162***	0.034	1.175***	0.172***	0.034	1.188***	0.172***	0.034	1.188***
Coagulopathy			-0.174	0.098	0.841	-0.167	0.097	0.846	-0.168	0.097	0.846
Depression			-0.095	0.054	0.910	-0.086	0.054	0.918	-0.086	0.054	0.918
Diabetes, uncomplicated			0.065	0.039	1.068	0.067	0.039	1.070	0.068	0.039	1.070
Diabetes w/ chronic complications			0.121	0.076	1.129	0.121	0.076	1.128	0.121	0.076	1.129
Drug abuse			0.136	0.234	1.146	0.131	0.234	1.140	0.133	0.234	1.142
Hypertension			-0.032	0.036	0.969	-0.018	0.036	0.982	-0.018	0.036	0.982
Hypothyroidism			-0.011	0.044	0.989	-0.007	0.044	0.993	-0.007	0.044	0.993
Liver disease			0.173	0.135	1.189	0.175	0.135	1.192	0.177	0.135	1.194
Lymphoma			-0.279	0.239	0.757	-0.259	0.239	0.772	-0.259	0.239	0.772
Fluid and electrolyte disorders			0.050	0.034	1.051	0.054	0.035	1.055	0.054	0.035	1.055
Metastatic cancer			0.094	0.269	1.098	0.099	0.269	1.104	0.100	0.269	1.105
Other neurological disorders			0.068	0.045	1.070	0.068	0.045	1.070	0.068	0.045	1.071
Obesity			-0.090	0.075	0.914	-0.075	0.075	0.928	-0.076	0.075	0.927
Paralysis			0.016	0.088	1.016	0.008	0.088	1.008	0.008	0.088	1.008
Peripheral vascular disorders			0.067	0.058	1.069	0.081	0.058	1.084	0.081	0.058	1.084
Psychoses			0.122	0.077	1.130	0.104	0.077	1.109	0.103	0.077	1.109
Pulmonary circulation disorders			0.077	0.075	1.080	0.092	0.075	1.097	0.093	0.075	1.097
Renal failure			0.122**	0.045	1.129**	0.125**	0.045	1.133**	0.124**	0.045	1.132**
Solid tumor without metastasis			-0.044	0.091	0.957	-0.039	0.091	0.962	-0.038	0.091	0.963
Peptic ulcer disease			0.628	0.527	1.873	0.614	0.526	1.849	0.614	0.527	1.847
Valvular disease			-0.024	0.055	0.977	-0.004	0.055	0.996	-0.004	0.055	0.996
Weight loss			0.168*	0.072	1.183*	0.169*	0.072	1.184*	0.170*	0.072	1.185*

Level 2: Hospital Characteristics											
California (Ref: Florida)						-0.115*	0.052	0.892*	-0.111*	0.052	0.895*
Ownership (Ref: Public)											
Private, not-for-profit						0.043	0.068	1.044	0.053	0.068	1.054
Private, for-profit						-0.032	0.078	0.968	-0.032	0.078	0.968
System affiliation						0.060	0.054	1.061	0.060	0.054	1.062
Cardiac catherization facility						-0.084	0.062	0.920	-0.072	0.063	0.930
Magnet hospital						-0.197*	0.100	0.822*	-0.223*	0.101	0.800*
Teaching intensity (Ref: non-teaching)											
Low						0.059	0.070	1.061	0.058	0.070	1.060
Medium						-0.072	0.076	0.931	-0.069	0.076	0.933
High						0.046	0.113	1.047	0.049	0.113	1.050
Hospital location (Ref: Rural)											
Micro/Division						0.024	0.106	1.024	0.023	0.106	1.023
Metro						-0.085	0.099	0.918	-0.084	0.099	0.919
Disproportionate Share Hospital (DSH) Index						-0.003	0.163	0.997	-0.041	0.165	0.960
Mean number of Elixhauser comorbid conditions						-0.103*	0.050	0.902*	-0.098*	0.050	0.907*
Proportion of patients with prior hospitalization for both PN and other conditions						2.186**	0.688	8.899**	2.174**	0.687	8.791**
Hospital PN Volume						-0.000	0.000	1.000	-0.001	0.000	0.999
PQM (%): Discharge Composite Measure						-0.002*	0.001	0.998*	-0.005*	0.002	0.995*
Interaction (Volume × PQM)									0.000	0.000	1.000
Random effects											
Hospital (intercept)											
Variance between hospitals	0.111***		0.096***			0.062***			0.062***		
ICC	0.033		0.028			0.018			0.018		
MOR	1.375		1.345			1.267			1.267		

n: level-1 (patients)	36374		36374			36374			36374		
n: level-2 (hospitals)	424		424			424			424		
AIC	27090		26210			26177			26177		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3$ =3.29.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 16:
Association of PN-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (Global Composite Measure)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.003	0.002	1.003	0.003	0.002	1.003	0.003	0.002	1.003
Female			-0.127***	0.034	0.881***	-0.132***	0.034	0.877***	-0.131***	0.034	0.877***
Race (Ref: White)											
Black			0.076	0.076	1.079	0.053	0.077	1.054	0.052	0.077	1.053
Hispanic			0.037	0.057	1.038	-0.011	0.057	0.989	-0.010	0.058	0.990
Others			-0.070	0.071	0.932	-0.149*	0.072	0.861*	-0.146*	0.072	0.865*
Disposition (Ref=Routine)											
Home Health Care			0.288***	0.049	1.334***	0.299***	0.049	1.348***	0.299***	0.049	1.349***
Nursing Home			0.760***	0.040	2.137***	0.754***	0.040	2.126***	0.754***	0.040	2.126***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.065	0.047	0.937	-0.064	0.047	0.938	-0.064	0.047	0.938
3rd quartile			-0.007	0.049	0.993	-0.002	0.049	0.998	-0.001	0.049	0.999
4th quartile			-0.018	0.054	0.982	-0.010	0.055	0.990	-0.008	0.055	0.992
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than PN			0.097	0.170	1.101	0.083	0.170	1.086	0.082	0.170	1.086
Prior admission (1y) for PN			0.367***	0.036	1.444***	0.365***	0.036	1.441***	0.365***	0.036	1.440***
Prior admission (1y) for both PN and other conditions			0.644***	0.057	1.904***	0.619***	0.058	1.856***	0.618***	0.058	1.856***
Comorbidities											

AIDS											
Alcohol abuse			0.208	0.125	1.231	0.201	0.125	1.222	0.200	0.125	1.221
Deficiency anemias			0.027	0.037	1.027	0.028	0.037	1.028	0.028	0.037	1.028
Rheumatoid arthritis			0.226**	0.082	1.254**	0.236**	0.082	1.267**	0.236**	0.082	1.266**
Chronic blood loss anemia			-0.011	0.158	0.989	0.004	0.158	1.004	0.005	0.158	1.005
Congest Heart Failure			0.199***	0.037	1.220***	0.192***	0.036	1.212***	0.193***	0.037	1.212***
Chronic pulmonary disease			0.161***	0.034	1.175***	0.172***	0.034	1.187***	0.172***	0.034	1.188***
Coagulopathy			-0.174	0.098	0.840	-0.166	0.097	0.847	-0.166	0.097	0.847
Depression			-0.095	0.054	0.910	-0.085	0.054	0.918	-0.086	0.054	0.918
Diabetes, uncomplicated			0.065	0.039	1.067	0.068	0.039	1.070	0.068	0.039	1.071
Diabetes w/ chronic complications			0.121	0.076	1.129	0.120	0.076	1.127	0.120	0.076	1.128
Drug abuse			0.136	0.234	1.146	0.133	0.234	1.143	0.134	0.234	1.144
Hypertension			-0.032	0.036	0.968	-0.018	0.036	0.982	-0.019	0.036	0.982
Hypothyroidism			-0.012	0.044	0.988	-0.007	0.044	0.993	-0.007	0.044	0.993
Liver disease			0.173	0.135	1.189	0.176	0.135	1.192	0.177	0.135	1.194
Lymphoma			-0.279	0.239	0.757	-0.257	0.239	0.773	-0.258	0.239	0.773
Fluid and electrolyte disorders			0.049	0.034	1.051	0.054	0.034	1.055	0.054	0.035	1.055
Metastatic cancer			0.094	0.269	1.098	0.101	0.269	1.107	0.103	0.269	1.109
Other neurological disorders			0.068	0.045	1.070	0.068	0.045	1.070	0.068	0.045	1.070
Obesity			-0.090	0.075	0.914	-0.075	0.075	0.928	-0.075	0.075	0.927
Paralysis			0.016	0.088	1.016	0.008	0.088	1.008	0.008	0.088	1.008
Peripheral vascular disorders			0.066	0.058	1.069	0.081	0.058	1.084	0.081	0.058	1.084
Psychoses			0.122	0.077	1.130	0.103	0.077	1.108	0.102	0.077	1.107
Pulmonary circulation disorders			0.077	0.075	1.080	0.093	0.075	1.097	0.093	0.075	1.097
Renal failure			0.121**	0.045	1.129**	0.125**	0.045	1.133**	0.124**	0.045	1.132**
Solid tumor without metastasis			-0.044	0.091	0.957	-0.039	0.091	0.962	-0.038	0.091	0.963
Peptic ulcer disease			0.628	0.527	1.873	0.618	0.526	1.856	0.620	0.526	1.859
Valvular disease			-0.024	0.055	0.976	-0.004	0.055	0.996	-0.004	0.055	0.996
Weight loss			0.168*	0.072	1.183*	0.168*	0.072	1.182*	0.168*	0.072	1.183*

Level 2: Hospital Characteristics											
California (Ref: Florida)						-0.119*	0.052	0.888*	-0.113*	0.052	0.893*
Ownership (Ref: Public)											
Private, not-for-profit						0.038	0.068	1.039	0.041	0.068	1.042
Private, for-profit						-0.043	0.078	0.958	-0.047	0.079	0.954
System affiliation						0.069	0.054	1.071	0.066	0.054	1.068
Cardiac catherization facility						-0.081	0.062	0.922	-0.071	0.063	0.932
Magnet hospital						-0.190	0.100	0.827	-0.217*	0.102	0.805*
Teaching intensity (Ref: non-teaching)											
Low						0.067	0.070	1.069	0.065	0.070	1.067
Medium						-0.068	0.076	0.934	-0.066	0.076	0.936
High						0.047	0.112	1.048	0.047	0.112	1.048
Hospital location (Ref: Rural)											
Micro/Division						0.024	0.106	1.025	0.024	0.106	1.024
Metro						-0.084	0.099	0.919	-0.082	0.099	0.921
Disproportionate Share Hospital (DSH) Index						-0.022	0.163	0.979	-0.051	0.165	0.951
Mean number of Elixhauser comorbid conditions						-0.105*	0.049	0.901*	-0.100*	0.049	0.905*
Proportion of patients with prior hospitalization for both PN and other conditions						2.200**	0.685	9.022**	2.188**	0.685	8.915**
Hospital PN Volume						-0.000	0.000	1.000	-0.001	0.000	0.999
PQM (%): Global Composite Measure						-0.008*	0.003	0.992*	-0.014*	0.005	0.986*
Interaction (Volume × PQM)									0.000	0.000	1.000
Random effects											
Hospital (intercept)											
Variance between hospitals	0.111***		0.096***			0.061***			0.061***		
ICC	0.033		0.028			0.018			0.018		
MOR	1.375		1.345			1.265			1.265		

n: level-1 (patients)	36378		36378			36378			36378		
n: level-2 (hospitals)	425		425			425			425		
AIC	27095		26215			26179			26179		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3$ =3.29.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 17:
Association of PN-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (Assessed and Given Influenza Vaccination)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.003	0.002	1.003	0.003	0.002	1.003	0.003	0.002	1.003
Female			-0.128***	0.034	0.880***	-0.133***	0.034	0.876***	-0.133***	0.034	0.876***
Race (Ref: White)											
Black			0.081	0.077	1.084	0.055	0.077	1.057	0.056	0.077	1.057
Hispanic			0.043	0.057	1.044	-0.008	0.058	0.992	-0.008	0.058	0.992
Others			-0.067	0.072	0.936	-0.149*	0.073	0.861*	-0.146*	0.073	0.864*
Disposition (Ref=Routine)											
Home Health Care			0.293***	0.049	1.340***	0.304***	0.049	1.355***	0.305***	0.049	1.356***
Nursing Home			0.764***	0.041	2.147***	0.760***	0.041	2.139***	0.760***	0.041	2.139***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.063	0.048	0.939	-0.064	0.047	0.938	-0.063	0.047	0.939
3rd quartile			-0.006	0.049	0.994	-0.007	0.049	0.993	-0.006	0.049	0.994
4th quartile			-0.024	0.054	0.976	-0.022	0.056	0.978	-0.020	0.056	0.980
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than PN			0.101	0.170	1.106	0.087	0.170	1.090	0.086	0.170	1.090
Prior admission (1y) for PN			0.363***	0.036	1.438***	0.361***	0.036	1.435***	0.361***	0.036	1.435***
Prior admission (1y) for both PN and other conditions			0.645***	0.058	1.907***	0.620***	0.058	1.859***	0.620***	0.058	1.859***
Comorbidities											

AIDS											
Alcohol abuse			0.222	0.125	1.249	0.215	0.125	1.240	0.214	0.125	1.239
Deficiency anemias			0.024	0.037	1.024	0.025	0.037	1.025	0.024	0.037	1.025
Rheumatoid arthritis			0.228**	0.082	1.256**	0.237**	0.082	1.267**	0.237**	0.082	1.267**
Chronic blood loss anemia			-0.002	0.158	0.998	0.011	0.158	1.011	0.011	0.158	1.012
Congest Heart Failure			0.193***	0.037	1.213***	0.188***	0.037	1.206***	0.188***	0.037	1.207***
Chronic pulmonary disease			0.164***	0.035	1.179***	0.175***	0.035	1.191***	0.175***	0.035	1.191***
Coagulopathy			-0.187	0.099	0.829	-0.180	0.099	0.835	-0.181	0.099	0.834
Depression			-0.096	0.054	0.908	-0.087	0.054	0.917	-0.087	0.054	0.917
Diabetes, uncomplicated			0.066	0.039	1.068	0.068	0.039	1.070	0.068	0.039	1.070
Diabetes w/ chronic complications			0.123	0.076	1.130	0.120	0.076	1.127	0.120	0.076	1.127
Drug abuse			0.090	0.238	1.094	0.085	0.238	1.089	0.087	0.238	1.091
Hypertension			-0.031	0.036	0.969	-0.018	0.036	0.982	-0.018	0.036	0.982
Hypothyroidism			-0.014	0.044	0.987	-0.009	0.044	0.991	-0.009	0.044	0.991
Liver disease			0.175	0.135	1.192	0.177	0.135	1.193	0.178	0.135	1.195
Lymphoma			-0.258	0.240	0.773	-0.239	0.240	0.787	-0.239	0.240	0.787
Fluid and electrolyte disorders			0.051	0.035	1.052	0.055	0.035	1.057	0.055	0.035	1.057
Metastatic cancer			0.016	0.284	1.016	0.022	0.284	1.022	0.023	0.284	1.024
Other neurological disorders			0.069	0.045	1.071	0.069	0.045	1.071	0.069	0.045	1.071
Obesity			-0.091	0.076	0.913	-0.076	0.076	0.927	-0.076	0.076	0.927
Paralysis			0.017	0.088	1.018	0.008	0.088	1.008	0.008	0.088	1.008
Peripheral vascular disorders			0.068	0.058	1.071	0.082	0.058	1.085	0.082	0.058	1.085
Psychoses			0.127	0.077	1.135	0.109	0.078	1.115	0.108	0.078	1.114
Pulmonary circulation disorders			0.080	0.076	1.083	0.095	0.076	1.099	0.095	0.076	1.100
Renal failure			0.127**	0.046	1.135**	0.129**	0.046	1.138**	0.129**	0.046	1.137**
Solid tumor without metastasis			-0.047	0.092	0.954	-0.042	0.092	0.959	-0.041	0.092	0.959
Peptic ulcer disease			0.629	0.527	1.876	0.607	0.527	1.836	0.609	0.527	1.839
Valvular disease			-0.021	0.055	0.979	-0.002	0.055	0.998	-0.001	0.055	0.999
Weight loss			0.165*	0.073	1.179*	0.164*	0.073	1.178*	0.165*	0.073	1.179*

Level 2: Hospital Characteristics											
California (Ref: Florida)						-0.111*	0.053	0.895*	-0.106*	0.053	0.899*
Ownership (Ref: Public)											
Private, not-for-profit						0.047	0.069	1.048	0.053	0.069	1.054
Private, for-profit						-0.042	0.079	0.959	-0.041	0.079	0.960
System affiliation						0.068	0.055	1.071	0.066	0.055	1.068
Cardiac catherization facility						-0.092	0.063	0.913	-0.084	0.063	0.919
Magnet hospital						-0.203*	0.100	0.816*	-0.217*	0.101	0.805*
Teaching intensity (Ref: non-teaching)											
Low						0.060	0.071	1.062	0.061	0.071	1.063
Medium						-0.087	0.076	0.917	-0.082	0.076	0.921
High						0.054	0.118	1.056	0.044	0.119	1.045
Hospital location (Ref: Rural)											
Micro/Division						0.051	0.108	1.053	0.049	0.108	1.050
Metro						-0.061	0.102	0.941	-0.062	0.102	0.940
Disproportionate Share Hospital (DSH) Index						0.001	0.165	1.002	-0.026	0.166	0.974
Mean number of Elixhauser comorbid conditions						-0.101*	0.050	0.904*	-0.098*	0.050	0.907*
Proportion of patients with prior hospitalization for both PN and other conditions						2.263**	0.705	9.616**	2.276**	0.704	9.739**
Hospital PN Volume						-0.000	0.000	1.000	-0.001	0.000	0.999
PQM (%): Assessed and Given Influenza Vaccination						-0.003*	0.001	0.997*	-0.005*	0.002	0.995*
Interaction (Volume × PQM)									0.000	0.000	1.000
Random effects											
Hospital (intercept)											
Variance between hospitals	0.113***		0.098***			0.062***			0.062***		
ICC	0.033		0.029			0.018			0.018		
MOR	1.379		1.348			1.267			1.267		

n: level-1 (patients)	35964		35964			35964			35964		
n: level-2 (hospitals)	411		411			411			411		
AIC	26776		25904			25870			25871		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3$ =3.29.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 18:
Association of PN-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (Assessed and Given Pneumococcal Vaccination)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.003	0.002	1.003	0.003	0.002	1.003	0.003	0.002	1.003
Female			-0.128***	0.034	0.880***	-0.132***	0.034	0.877***	-0.132***	0.034	0.877***
Race (Ref: White)											
Black			0.076	0.076	1.079	0.055	0.077	1.057	0.055	0.077	1.057
Hispanic			0.037	0.057	1.038	-0.012	0.058	0.988	-0.011	0.058	0.989
Others			-0.070	0.071	0.933	-0.150*	0.072	0.861*	-0.145*	0.072	0.865*
Disposition (Ref=Routine)											
Home Health Care			0.287***	0.049	1.332***	0.297***	0.049	1.346***	0.297***	0.049	1.346***
Nursing Home			0.760***	0.040	2.138***	0.755***	0.040	2.128***	0.755***	0.040	2.128***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.065	0.047	0.937	-0.067	0.047	0.935	-0.067	0.047	0.935
3rd quartile			-0.007	0.049	0.993	-0.005	0.049	0.995	-0.003	0.049	0.997
4th quartile			-0.018	0.054	0.982	-0.013	0.055	0.987	-0.012	0.055	0.989
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than PN			0.096	0.170	1.101	0.084	0.170	1.087	0.084	0.170	1.088
Prior admission (1y) for PN			0.367***	0.036	1.443***	0.365***	0.036	1.440***	0.365***	0.036	1.440***
Prior admission (1y) for both PN and other conditions			0.644***	0.057	1.904***	0.619***	0.058	1.857***	0.619***	0.058	1.857***
Comorbidities											

AIDS											
Alcohol abuse			0.207	0.125	1.230	0.200	0.125	1.221	0.198	0.125	1.218
Deficiency anemias			0.027	0.037	1.027	0.028	0.037	1.028	0.028	0.037	1.028
Rheumatoid arthritis			0.227**	0.082	1.254**	0.236**	0.082	1.266**	0.235**	0.082	1.265**
Chronic blood loss anemia			-0.011	0.158	0.989	0.005	0.158	1.005	0.006	0.158	1.006
Congest Heart Failure			0.198***	0.037	1.219***	0.192***	0.037	1.211***	0.192***	0.037	1.211***
Chronic pulmonary disease			0.162***	0.034	1.175***	0.172***	0.034	1.188***	0.172***	0.034	1.188***
Coagulopathy			-0.174	0.098	0.841	-0.167	0.097	0.847	-0.167	0.097	0.846
Depression			-0.095	0.054	0.910	-0.086	0.054	0.918	-0.086	0.054	0.917
Diabetes, uncomplicated			0.065	0.039	1.068	0.067	0.039	1.070	0.068	0.039	1.070
Diabetes w/ chronic complications			0.121	0.076	1.129	0.121	0.076	1.129	0.122	0.076	1.130
Drug abuse			0.136	0.234	1.146	0.130	0.234	1.139	0.132	0.234	1.141
Hypertension			-0.032	0.036	0.969	-0.019	0.036	0.982	-0.018	0.036	0.982
Hypothyroidism			-0.011	0.044	0.989	-0.007	0.044	0.993	-0.007	0.044	0.993
Liver disease			0.173	0.135	1.189	0.175	0.135	1.192	0.177	0.135	1.194
Lymphoma			-0.279	0.239	0.757	-0.259	0.239	0.772	-0.259	0.239	0.772
Fluid and electrolyte disorders			0.050	0.034	1.051	0.054	0.035	1.055	0.054	0.035	1.055
Metastatic cancer			0.094	0.269	1.098	0.098	0.269	1.103	0.100	0.269	1.105
Other neurological disorders			0.068	0.045	1.070	0.068	0.045	1.070	0.069	0.045	1.071
Obesity			-0.090	0.075	0.914	-0.075	0.075	0.928	-0.076	0.075	0.927
Paralysis			0.016	0.088	1.016	0.008	0.088	1.008	0.008	0.088	1.008
Peripheral vascular disorders			0.067	0.058	1.069	0.081	0.058	1.084	0.081	0.058	1.084
Psychoses			0.122	0.077	1.130	0.104	0.077	1.110	0.104	0.077	1.109
Pulmonary circulation disorders			0.077	0.075	1.080	0.092	0.075	1.097	0.092	0.075	1.097
Renal failure			0.122**	0.045	1.129**	0.125**	0.045	1.133**	0.124**	0.045	1.132**
Solid tumor without metastasis			-0.044	0.091	0.957	-0.039	0.091	0.962	-0.038	0.091	0.963
Peptic ulcer disease			0.628	0.527	1.873	0.615	0.526	1.850	0.614	0.526	1.847
Valvular disease			-0.024	0.055	0.977	-0.004	0.055	0.996	-0.004	0.055	0.996
Weight loss			0.168*	0.072	1.183*	0.169*	0.072	1.184*	0.170*	0.072	1.185*

Level 2: Hospital Characteristics											
California (Ref: Florida)						-0.115*	0.052	0.892*	-0.112*	0.052	0.894*
Ownership (Ref: Public)											
Private, not-for-profit						0.044	0.068	1.045	0.055	0.068	1.056
Private, for-profit						-0.029	0.078	0.971	-0.030	0.078	0.970
System affiliation						0.056	0.054	1.058	0.057	0.054	1.059
Cardiac catherization facility						-0.084	0.062	0.920	-0.071	0.063	0.932
Magnet hospital						-0.198*	0.100	0.820*	-0.226*	0.102	0.797*
Teaching intensity (Ref: non-teaching)											
Low						0.058	0.070	1.059	0.055	0.070	1.057
Medium						-0.070	0.076	0.932	-0.069	0.076	0.933
High						0.053	0.112	1.054	0.056	0.112	1.058
Hospital location (Ref: Rural)											
Micro/Division						0.026	0.106	1.026	0.025	0.106	1.025
Metro						-0.083	0.099	0.920	-0.081	0.099	0.922
Disproportionate Share Hospital (DSH) Index						0.002	0.164	1.002	-0.038	0.166	0.963
Mean number of Elixhauser comorbid conditions						-0.103*	0.050	0.902*	-0.097	0.050	0.908
Proportion of patients with prior hospitalization for both PN and other conditions						2.183**	0.688	8.872**	2.166**	0.687	8.725**
Hospital PN Volume)						-0.000	0.000	1.000	-0.001	0.000	0.999
PQM (%):Assessed and Given Pneumococcal Vaccination						-0.002	0.001	0.998	-0.005*	0.002	0.995*
Interaction (Volume × PQM)									0.000	0.000	1.000
Random effects											
Hospital (intercept)											
Variance between hospitals	0.111***		0.096***			0.062***			0.062***		
ICC	0.033		0.028			0.019			0.018		
MOR	1.375		1.345			1.268			1.268		

n: level-1 (patients)	36374		36374			36374			36374		
n: level-2 (hospitals)	424		424			424			424		
AIC	27090		26210			26178			26177		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3 = 3.29$.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 19:
Association of PN-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (Initial Antibiotic(s) within 6h After Arrival)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.002	0.002	1.002	0.002	0.002	1.002	0.002	0.002	1.002
Female			-0.120***	0.035	0.887***	-0.125***	0.035	0.882***	-0.125***	0.035	0.882***
Race (Ref: White)											
Black			0.069	0.078	1.071	0.041	0.078	1.042	0.041	0.078	1.042
Hispanic			0.023	0.058	1.023	-0.030	0.059	0.971	-0.030	0.059	0.971
Others			-0.046	0.073	0.955	-0.127	0.074	0.881	-0.127	0.074	0.881
Disposition (Ref=Routine)											
Home Health Care			0.297***	0.049	1.346***	0.307***	0.049	1.359***	0.307***	0.049	1.359***
Nursing Home			0.761***	0.041	2.140***	0.758***	0.041	2.134***	0.758***	0.041	2.135***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.081	0.048	0.922	-0.084	0.048	0.919	-0.084	0.048	0.919
3rd quartile			-0.028	0.050	0.973	-0.027	0.050	0.974	-0.028	0.050	0.973
4th quartile			-0.031	0.055	0.970	-0.033	0.056	0.967	-0.034	0.056	0.966
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than PN			0.114	0.173	1.120	0.100	0.173	1.105	0.100	0.173	1.106
Prior admission (1y) for PN			0.352***	0.036	1.422***	0.351***	0.036	1.421***	0.351***	0.036	1.421***
Prior admission (1y) for both PN and other conditions			0.639***	0.059	1.894***	0.617***	0.059	1.854***	0.617***	0.059	1.854***
Comorbidities											

AIDS											
Alcohol abuse			0.209	0.127	1.232	0.196	0.127	1.217	0.197	0.127	1.218
Deficiency anemias			0.028	0.037	1.028	0.027	0.037	1.027	0.027	0.037	1.027
Rheumatoid arthritis			0.223**	0.083	1.250**	0.233**	0.083	1.262**	0.233**	0.083	1.262**
Chronic blood loss anemia			-0.022	0.161	0.979	-0.007	0.161	0.993	-0.007	0.161	0.993
Congest Heart Failure			0.200***	0.037	1.221***	0.192***	0.037	1.212***	0.192***	0.037	1.212***
Chronic pulmonary disease			0.169***	0.035	1.184***	0.178***	0.035	1.195***	0.178***	0.035	1.195***
Coagulopathy			-0.176	0.099	0.839	-0.166	0.099	0.847	-0.166	0.099	0.847
Depression			-0.082	0.054	0.922	-0.074	0.054	0.929	-0.074	0.054	0.929
Diabetes, uncomplicated			0.062	0.040	1.064	0.064	0.040	1.066	0.064	0.040	1.066
Diabetes w/ chronic complications			0.102	0.078	1.107	0.099	0.078	1.104	0.099	0.078	1.104
Drug abuse			0.059	0.243	1.061	0.043	0.243	1.044	0.043	0.243	1.044
Hypertension			-0.018	0.037	0.982	-0.009	0.037	0.991	-0.009	0.037	0.991
Hypothyroidism			-0.013	0.045	0.987	-0.010	0.045	0.990	-0.009	0.045	0.991
Liver disease			0.188	0.136	1.206	0.187	0.136	1.205	0.187	0.136	1.205
Lymphoma			-0.294	0.245	0.745	-0.273	0.245	0.761	-0.273	0.245	0.761
Fluid and electrolyte disorders			0.053	0.035	1.054	0.057	0.035	1.059	0.057	0.035	1.059
Metastatic cancer			0.040	0.284	1.041	0.049	0.284	1.050	0.048	0.284	1.049
Other neurological disorders			0.070	0.046	1.072	0.068	0.046	1.070	0.068	0.046	1.070
Obesity			-0.119	0.077	0.888	-0.104	0.077	0.902	-0.104	0.077	0.902
Paralysis			0.042	0.089	1.042	0.033	0.089	1.033	0.033	0.089	1.034
Peripheral vascular disorders			0.074	0.059	1.077	0.087	0.059	1.091	0.087	0.059	1.091
Psychoses			0.137	0.079	1.147	0.125	0.079	1.133	0.125	0.079	1.133
Pulmonary circulation disorders			0.081	0.076	1.085	0.095	0.076	1.099	0.095	0.076	1.099
Renal failure			0.123**	0.046	1.131**	0.124**	0.046	1.132**	0.124**	0.046	1.132**
Solid tumor without metastasis			-0.044	0.093	0.957	-0.039	0.093	0.962	-0.039	0.093	0.961
Peptic ulcer disease			0.629	0.526	1.875	0.606	0.526	1.834	0.604	0.526	1.830
Valvular disease			-0.023	0.056	0.977	-0.006	0.056	0.994	-0.006	0.056	0.994
Weight loss			0.149*	0.074	1.160*	0.149*	0.074	1.161*	0.149*	0.074	1.161*

Level 2: Hospital Characteristics											
California (Ref: Florida)						-0.145**	0.053	0.865**	-0.149**	0.054	0.862**
Ownership (Ref: Public)											
Private, not-for-profit						0.036	0.070	1.037	0.036	0.070	1.037
Private, for-profit						-0.010	0.081	0.990	-0.007	0.081	0.993
System affiliation						0.060	0.056	1.062	0.059	0.056	1.061
Cardiac catherization facility						-0.101	0.064	0.904	-0.099	0.064	0.906
Magnet hospital						-0.182	0.100	0.834	-0.173	0.102	0.841
Teaching intensity (Ref: non-teaching)											
Low						0.032	0.071	1.033	0.031	0.071	1.031
Medium						-0.075	0.076	0.928	-0.078	0.076	0.925
High						0.039	0.121	1.040	0.049	0.122	1.051
Hospital location (Ref: Rural)											
Micro/Division						0.076	0.112	1.079	0.076	0.112	1.079
Metro						-0.046	0.105	0.955	-0.047	0.105	0.954
Disproportionate Share Hospital (DSH) Index						-0.020	0.172	0.980	-0.017	0.172	0.983
Mean number of Elixhauser comorbid conditions						-0.086	0.051	0.917	-0.085	0.051	0.918
Proportion of patients with prior hospitalization for both PN and other conditions						2.100**	0.729	8.168**	2.090**	0.729	8.082**
Hospital PN Volume						-0.000	0.000	1.000	-0.001	0.000	0.999
PQM (%): Initial Antibiotic(s) within 6h After Arrival						-0.007	0.004	0.993	-0.004	0.006	0.996
Interaction (Volume × PQM)									-0.000	0.000	1.000
Random effects											
Hospital (intercept)											
Variance between hospitals	0.109***		0.093***			0.060***			0.060***		
ICC	0.032		0.027			0.018			0.018		
MOR	1.370		1.337			1.262			1.262		

n: level-1 (patients)	35202		35202			35202			35202		
n: level-2 (hospitals)	394		394			394			394		
AIC	26028		25201			25177			25179		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3$ =3.29.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 20:
Association of PN-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (Oxygenation Assessment)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.003	0.002	1.003	0.003	0.002	1.003	0.003	0.002	1.003
Female			-0.128***	0.034	0.880***	-0.131***	0.034	0.877***	-0.131***	0.034	0.877***
Race (Ref: White)											
Black			0.076	0.076	1.079	0.058	0.076	1.059	0.056	0.076	1.057
Hispanic			0.041	0.056	1.041	-0.007	0.057	0.993	-0.003	0.057	0.997
Others			-0.070	0.071	0.933	-0.148*	0.072	0.863*	-0.147*	0.072	0.863*
Disposition (Ref=Routine)											
Home Health Care			0.287***	0.049	1.332***	0.297***	0.049	1.345***	0.296***	0.049	1.345***
Nursing Home			0.758***	0.040	2.134***	0.754***	0.040	2.124***	0.753***	0.040	2.124***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.063	0.047	0.939	-0.063	0.047	0.939	-0.066	0.047	0.937
3rd quartile			-0.006	0.049	0.994	-0.001	0.049	0.999	-0.006	0.049	0.994
4th quartile			-0.018	0.054	0.982	-0.009	0.055	0.991	-0.012	0.055	0.988
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than PN			0.095	0.170	1.100	0.082	0.170	1.086	0.083	0.170	1.086
Prior admission (1y) for PN			0.366***	0.036	1.442***	0.365***	0.036	1.441***	0.365***	0.036	1.440***
Prior admission (1y) for both PN and other conditions			0.642***	0.057	1.901***	0.616***	0.058	1.852***	0.616***	0.058	1.852***
Comorbidities											

AIDS											
Alcohol abuse			0.207	0.125	1.231	0.200	0.125	1.221	0.199	0.125	1.220
Deficiency anemias			0.027	0.037	1.028	0.029	0.037	1.029	0.029	0.037	1.029
Rheumatoid arthritis			0.226**	0.082	1.253**	0.236**	0.082	1.266**	0.235**	0.082	1.264**
Chronic blood loss anemia			-0.011	0.158	0.989	0.006	0.158	1.006	0.005	0.158	1.005
Congest Heart Failure			0.198***	0.037	1.219***	0.191***	0.036	1.210***	0.191***	0.036	1.210***
Chronic pulmonary disease			0.160***	0.034	1.173***	0.172***	0.034	1.187***	0.172***	0.034	1.188***
Coagulopathy			-0.174	0.098	0.840	-0.167	0.097	0.846	-0.168	0.097	0.846
Depression			-0.095	0.054	0.909	-0.087	0.054	0.917	-0.087	0.054	0.917
Diabetes, uncomplicated			0.066	0.039	1.068	0.069	0.039	1.072	0.069	0.039	1.072
Diabetes w/ chronic complications			0.121	0.076	1.129	0.122	0.076	1.130	0.122	0.076	1.130
Drug abuse			0.136	0.234	1.146	0.128	0.234	1.137	0.128	0.234	1.136
Hypertension			-0.033	0.036	0.968	-0.020	0.036	0.980	-0.020	0.036	0.981
Hypothyroidism			-0.008	0.044	0.992	-0.003	0.044	0.997	-0.003	0.044	0.997
Liver disease			0.172	0.135	1.188	0.174	0.135	1.190	0.174	0.135	1.190
Lymphoma			-0.279	0.239	0.756	-0.260	0.239	0.771	-0.259	0.239	0.772
Fluid and electrolyte disorders			0.050	0.034	1.051	0.055	0.034	1.056	0.054	0.034	1.056
Metastatic cancer			0.094	0.269	1.098	0.099	0.269	1.104	0.100	0.269	1.105
Other neurological disorders			0.067	0.045	1.069	0.068	0.045	1.070	0.068	0.045	1.070
Obesity			-0.090	0.075	0.914	-0.074	0.075	0.928	-0.075	0.075	0.928
Paralysis			0.016	0.088	1.016	0.008	0.088	1.008	0.008	0.088	1.008
Peripheral vascular disorders			0.066	0.058	1.069	0.080	0.058	1.084	0.081	0.058	1.084
Psychoses			0.122	0.077	1.130	0.106	0.077	1.112	0.109	0.077	1.116
Pulmonary circulation disorders			0.077	0.075	1.080	0.093	0.075	1.097	0.092	0.075	1.097
Renal failure			0.121**	0.045	1.129**	0.123**	0.045	1.131**	0.122**	0.045	1.130**
Solid tumor without metastasis			-0.044	0.091	0.957	-0.039	0.091	0.962	-0.039	0.091	0.962
Peptic ulcer disease			0.628	0.527	1.874	0.611	0.526	1.843	0.608	0.526	1.836
Valvular disease			-0.024	0.055	0.976	-0.005	0.055	0.995	-0.004	0.055	0.996
Weight loss			0.173*	0.072	1.189*	0.174*	0.072	1.190*	0.175*	0.072	1.192*

Level 2: Hospital Characteristics											
California (Ref: Florida)						-0.122*	0.052	0.885*	-0.114*	0.052	0.892*
Ownership (Ref: Public)											
Private, not-for-profit						0.037	0.068	1.037	0.042	0.068	1.043
Private, for-profit						-0.046	0.079	0.955	-0.041	0.079	0.960
System affiliation						0.049	0.053	1.050	0.042	0.053	1.043
Cardiac catherization facility						-0.085	0.062	0.918	-0.084	0.062	0.919
Magnet hospital						-0.222*	0.099	0.801*	-0.227*	0.099	0.797*
Teaching intensity (Ref: non-teaching)											
Low						0.049	0.070	1.051	0.043	0.070	1.043
Medium						-0.071	0.076	0.932	-0.068	0.075	0.935
High						0.083	0.111	1.087	0.083	0.111	1.086
Hospital location (Ref: Rural)											
Micro/Division						0.039	0.106	1.040	0.051	0.106	1.052
Metro						-0.071	0.099	0.931	-0.063	0.099	0.939
Disproportionate Share Hospital (DSH) Index						0.019	0.162	1.019	0.009	0.161	1.009
Mean number of Elixhauser comorbid conditions						-0.105*	0.049	0.900*	-0.098*	0.049	0.906*
Proportion of patients with prior hospitalization for both PN and other conditions						2.318***	0.687	10.154***	2.292***	0.684	9.898***
Hospital PN Volume						-0.001	0.000	0.999	-0.001	0.000	0.999
PQM (%): Oxygenation Assessment						-0.033	0.017	0.967	-0.056*	0.024	0.946*
Interaction (Volume × PQM)									0.001	0.001	1.001
Random effects											
Hospital (intercept)											
Variance between hospitals	0.111***		0.096***			0.061***			0.060***		
ICC	0.033		0.028			0.018			0.018		
MOR	1.375		1.345			1.267			1.263		

n: level-1 (patients)	36384		36384			36384			36384		
n: level-2 (hospitals)	426		426			426			426		
AIC	27104		26227			26193			26193		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3$ =3.29.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 21:
Association of PN-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (the Most Appropriate Initial Antibiotic(s))

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.003	0.002	1.003	0.003	0.002	1.003	0.003	0.002	1.003
Female			-0.130***	0.034	0.878***	-0.133***	0.034	0.875***	-0.133***	0.034	0.875***
Race (Ref: White)											
Black			0.079	0.076	1.082	0.060	0.077	1.062	0.060	0.077	1.062
Hispanic			0.040	0.057	1.041	-0.003	0.058	0.997	-0.003	0.058	0.997
Others			-0.068	0.071	0.934	-0.148*	0.072	0.863*	-0.149*	0.072	0.862*
Disposition (Ref=Routine)											
Home Health Care			0.289***	0.049	1.335***	0.300***	0.049	1.349***	0.300***	0.049	1.349***
Nursing Home			0.760***	0.041	2.139***	0.756***	0.041	2.129***	0.756***	0.041	2.130***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.064	0.047	0.938	-0.065	0.047	0.937	-0.064	0.047	0.938
3rd quartile			-0.007	0.049	0.993	-0.002	0.049	0.998	-0.001	0.049	0.999
4th quartile			-0.020	0.054	0.980	-0.007	0.055	0.993	-0.006	0.055	0.994
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than PN			0.097	0.170	1.102	0.084	0.170	1.088	0.084	0.170	1.088
Prior admission (1y) for PN			0.365***	0.036	1.441***	0.363***	0.036	1.438***	0.363***	0.036	1.438***
Prior admission (1y) for both PN and other conditions			0.644***	0.057	1.904***	0.619***	0.058	1.857***	0.619***	0.058	1.857***
Comorbidities											

AIDS											
Alcohol abuse			0.214	0.125	1.239	0.210	0.125	1.234	0.210	0.125	1.234
Deficiency anemias			0.025	0.037	1.025	0.026	0.037	1.026	0.026	0.037	1.026
Rheumatoid arthritis			0.227**	0.082	1.255**	0.238**	0.082	1.269**	0.238**	0.082	1.269**
Chronic blood loss anemia			-0.008	0.158	0.992	0.005	0.158	1.005	0.005	0.158	1.005
Congest Heart Failure			0.197***	0.037	1.217***	0.189***	0.037	1.208***	0.189***	0.037	1.208***
Chronic pulmonary disease			0.166***	0.034	1.181***	0.176***	0.035	1.192***	0.176***	0.035	1.192***
Coagulopathy			-0.173	0.098	0.841	-0.163	0.098	0.849	-0.163	0.098	0.849
Depression			-0.092	0.054	0.912	-0.083	0.054	0.920	-0.083	0.054	0.921
Diabetes, uncomplicated			0.067	0.039	1.069	0.070	0.039	1.072	0.070	0.039	1.072
Diabetes w/ chronic complications			0.120	0.076	1.127	0.116	0.076	1.123	0.116	0.076	1.124
Drug abuse			0.085	0.238	1.089	0.079	0.238	1.082	0.079	0.238	1.082
Hypertension			-0.033	0.036	0.968	-0.019	0.036	0.981	-0.019	0.036	0.981
Hypothyroidism			-0.015	0.044	0.985	-0.010	0.044	0.990	-0.010	0.044	0.990
Liver disease			0.172	0.135	1.187	0.172	0.135	1.187	0.171	0.135	1.186
Lymphoma			-0.275	0.239	0.760	-0.256	0.239	0.774	-0.256	0.239	0.774
Fluid and electrolyte disorders			0.052	0.035	1.053	0.057	0.035	1.059	0.057	0.035	1.059
Metastatic cancer			0.051	0.276	1.053	0.060	0.276	1.062	0.060	0.276	1.061
Other neurological disorders			0.071	0.045	1.073	0.072	0.045	1.074	0.072	0.045	1.074
Obesity			-0.095	0.076	0.909	-0.080	0.076	0.923	-0.080	0.076	0.923
Paralysis			0.020	0.088	1.020	0.013	0.088	1.013	0.013	0.088	1.013
Peripheral vascular disorders			0.069	0.058	1.071	0.085	0.058	1.089	0.085	0.058	1.088
Psychoses			0.124	0.077	1.132	0.102	0.077	1.108	0.102	0.077	1.108
Pulmonary circulation disorders			0.076	0.076	1.079	0.094	0.076	1.099	0.094	0.076	1.099
Renal failure			0.126**	0.046	1.134**	0.130**	0.046	1.139**	0.131**	0.046	1.139**
Solid tumor without metastasis			-0.038	0.092	0.963	-0.033	0.091	0.968	-0.033	0.091	0.968
Peptic ulcer disease			0.628	0.527	1.874	0.604	0.526	1.830	0.603	0.526	1.828
Valvular disease			-0.024	0.055	0.976	-0.007	0.055	0.993	-0.007	0.055	0.993
Weight loss			0.169*	0.072	1.184*	0.165*	0.072	1.180*	0.165*	0.072	1.180*

Level 2: Hospital Characteristics											
California (Ref: Florida)						-0.128*	0.052	0.880*	-0.129*	0.052	0.879*
Ownership (Ref: Public)											
Private, not-for-profit						0.038	0.068	1.039	0.040	0.068	1.040
Private, for-profit						-0.061	0.079	0.941	-0.059	0.079	0.942
System affiliation						0.070	0.054	1.073	0.073	0.054	1.076
Cardiac catherization facility						-0.075	0.062	0.928	-0.078	0.062	0.925
Magnet hospital						-0.209*	0.099	0.811*	-0.206*	0.100	0.814*
Teaching intensity (Ref: non-teaching)											
Low						0.067	0.070	1.069	0.068	0.070	1.070
Medium						-0.064	0.075	0.938	-0.065	0.075	0.937
High						0.085	0.117	1.089	0.086	0.117	1.090
Hospital location (Ref: Rural)											
Micro/Division						0.029	0.106	1.029	0.030	0.106	1.031
Metro						-0.077	0.099	0.926	-0.076	0.099	0.927
Disproportionate Share Hospital (DSH) Index						0.004	0.161	1.004	0.015	0.163	1.015
Mean number of Elixhauser comorbid conditions						-0.103*	0.049	0.902*	-0.104*	0.049	0.901*
Proportion of patients with prior hospitalization for both PN and other conditions						2.095**	0.685	8.123**	2.101**	0.685	8.175**
Hospital PN Volume						-0.001	0.000	0.999	-0.000	0.000	1.000
PQM (%):the Most Appropriate Initial Antibiotic(s)						-0.008**	0.003	0.992**	-0.007	0.005	0.993
Interaction (Volume × PQM)									-0.000	0.000	1.000
Random effects											
Hospital (intercept)											
Variance between hospitals	0.112***		0.097***			0.059***			0.059***		
ICC	0.033		0.029			0.018			0.018		
MOR	1.377		1.347			1.261			1.261		

n: level-1 (patients)	36172		36172			36172			36172		
n: level-2 (hospitals)	422		422			422			422		
AIC	26945		26068			26031			26033		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3$ =3.29.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.

Appendix Table 22:
Association of PN-PPR with individual- and hospital-level characteristics using hierarchical logistic regression (Initial ER Blood Culture Performed Prior To First Hospital Dose Of Antibiotics)

Parameter	Model 1		Model 2			Model 3			Model 4		
	Coef	SE	Coef	SE	aOR	Coef	SE	aOR	Coef	SE	aOR
Fixed effects											
Level 1: Patient Characteristics											
Socio-Demographic & Post-discharge											
Age			0.002	0.002	1.002	0.003	0.002	1.003	0.003	0.002	1.003
Female			-0.126***	0.034	0.882***	-0.130***	0.034	0.878***	-0.130***	0.034	0.878***
Race (Ref: White)											
Black			0.052	0.077	1.053	0.029	0.078	1.030	0.029	0.078	1.029
Hispanic			0.029	0.057	1.029	-0.016	0.058	0.984	-0.016	0.058	0.984
Others			-0.072	0.072	0.931	-0.148*	0.072	0.862*	-0.148*	0.072	0.862*
Disposition (Ref=Routine)											
Home Health Care			0.281***	0.049	1.325***	0.291***	0.049	1.338***	0.291***	0.049	1.338***
Nursing Home			0.749***	0.041	2.116***	0.747***	0.041	2.110***	0.747***	0.041	2.110***
Median Income Quartile (Ref=1st quartile: Poorest)											
2nd quartile			-0.075	0.048	0.928	-0.076	0.047	0.927	-0.076	0.047	0.927
3rd quartile			-0.007	0.049	0.993	-0.004	0.049	0.996	-0.005	0.049	0.995
4th quartile			-0.015	0.054	0.985	-0.012	0.055	0.988	-0.012	0.055	0.988
Severity											
Prior admission (1y) (Ref=No)											
Prior admission (1y) other than PN			0.105	0.170	1.111	0.090	0.170	1.094	0.090	0.170	1.094
Prior admission (1y) for PN			0.365***	0.036	1.440***	0.364***	0.036	1.439***	0.364***	0.036	1.439***
Prior admission (1y) for both PN and other conditions			0.641***	0.058	1.898***	0.617***	0.058	1.853***	0.617***	0.058	1.853***
Comorbidities											

AIDS											
Alcohol abuse			0.219	0.125	1.245	0.211	0.125	1.235	0.211	0.125	1.235
Deficiency anemias			0.024	0.037	1.024	0.024	0.037	1.024	0.024	0.037	1.024
Rheumatoid arthritis			0.229**	0.082	1.257**	0.238**	0.082	1.268**	0.238**	0.082	1.268**
Chronic blood loss anemia			-0.006	0.158	0.994	0.010	0.158	1.010	0.010	0.158	1.010
Congest Heart Failure			0.201***	0.037	1.223***	0.195***	0.037	1.215***	0.195***	0.037	1.215***
Chronic pulmonary disease			0.166***	0.035	1.180***	0.176***	0.035	1.193***	0.176***	0.035	1.192***
Coagulopathy			-0.165	0.098	0.848	-0.156	0.098	0.855	-0.156	0.098	0.855
Depression			-0.088	0.054	0.916	-0.080	0.054	0.923	-0.080	0.054	0.923
Diabetes, uncomplicated			0.071	0.039	1.074	0.073	0.039	1.075	0.073	0.039	1.075
Diabetes w/ chronic complications			0.115	0.076	1.122	0.116	0.076	1.123	0.116	0.076	1.123
Drug abuse			0.141	0.234	1.151	0.131	0.234	1.140	0.131	0.234	1.140
Hypertension			-0.032	0.036	0.968	-0.020	0.036	0.980	-0.020	0.036	0.980
Hypothyroidism			-0.011	0.044	0.989	-0.008	0.044	0.992	-0.008	0.044	0.992
Liver disease			0.173	0.135	1.189	0.173	0.135	1.188	0.173	0.135	1.189
Lymphoma			-0.275	0.239	0.760	-0.257	0.239	0.773	-0.257	0.239	0.773
Fluid and electrolyte disorders			0.052	0.035	1.054	0.057	0.035	1.058	0.057	0.035	1.058
Metastatic cancer			0.116	0.269	1.123	0.123	0.269	1.131	0.123	0.269	1.131
Other neurological disorders			0.074	0.045	1.077	0.073	0.045	1.076	0.073	0.045	1.076
Obesity			-0.090	0.076	0.914	-0.075	0.076	0.928	-0.075	0.076	0.928
Paralysis			0.016	0.088	1.016	0.009	0.088	1.009	0.009	0.088	1.009
Peripheral vascular disorders			0.069	0.058	1.071	0.082	0.058	1.086	0.082	0.058	1.086
Psychoses			0.129	0.078	1.137	0.114	0.078	1.121	0.114	0.078	1.121
Pulmonary circulation disorders			0.071	0.076	1.074	0.087	0.076	1.090	0.086	0.076	1.090
Renal failure			0.122**	0.046	1.130**	0.124**	0.046	1.132**	0.124**	0.046	1.132**
Solid tumor without metastasis			-0.033	0.091	0.967	-0.030	0.091	0.971	-0.030	0.091	0.971
Peptic ulcer disease			0.631	0.526	1.879	0.612	0.526	1.844	0.611	0.526	1.842
Valvular disease			-0.018	0.055	0.982	0.000	0.055	1.000	0.000	0.055	1.000
Weight loss			0.168*	0.073	1.183*	0.169*	0.073	1.184*	0.169*	0.073	1.185*

Level 2: Hospital Characteristics											
California (Ref: Florida)						-0.128*	0.053	0.880*	-0.127*	0.053	0.881*
Ownership (Ref: Public)											
Private, not-for-profit						0.055	0.068	1.057	0.054	0.068	1.056
Private, for-profit						-0.017	0.078	0.983	-0.018	0.078	0.982
System affiliation						0.054	0.055	1.056	0.053	0.055	1.055
Cardiac catherization facility						-0.080	0.062	0.923	-0.078	0.062	0.925
Magnet hospital						-0.198*	0.100	0.820*	-0.203*	0.101	0.816*
Teaching intensity (Ref: non-teaching)											
Low						0.052	0.069	1.054	0.052	0.069	1.053
Medium						-0.064	0.075	0.938	-0.066	0.075	0.936
High						0.063	0.112	1.066	0.058	0.114	1.059
Hospital location (Ref: Rural)											
Micro/Division						0.039	0.107	1.039	0.039	0.107	1.040
Metro						-0.081	0.100	0.922	-0.080	0.100	0.923
Disproportionate Share Hospital (DSH) Index						0.016	0.163	1.017	0.014	0.163	1.014
Mean number of Elixhauser comorbid conditions						-0.101*	0.050	0.904*	-0.100*	0.050	0.905*
Proportion of patients with prior hospitalization for both PN and other conditions						2.072**	0.700	7.943**	2.066**	0.701	7.894**
Hospital PN Volume						-0.000	0.000	1.000	-0.001	0.000	0.999
PQM (%): Initial ER Blood Culture Performed Prior To First Hospital Dose Of Antibiotics						-0.005	0.004	0.995	-0.007	0.007	0.993
Interaction (Volume × PQM)									0.000	0.000	1.000
Random effects											
Hospital (intercept)											
Variance between hospitals	0.105***		0.092***			0.058***			0.058***		
ICC	0.031		0.027			0.017			0.017		

MOR	1.362		1.335			1.259			1.259		
n: level-1 (patients)	36118		36118			36118			36118		
n: level-2 (hospitals)	415		415			415			415		
AIC	26863		26002			25976			25978		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ICC: Intraclass Correlation; Level-1 variance of hierarchical logistic model is $\pi^2/3$ =3.29.

MOR: Median Odds Ratio; = $\exp\{\sqrt{(2 \times \sigma_{u^2})} \times 0.6745\}$

PQM: Process Quality Measure

Model 1 is a null model; **Model 2** includes patient-level factors (level-1); **Model 3** includes Model 2 plus hospital-level factors; **Model 4** includes interaction based on Model 3.